

Decabromodiphenyl Ether Flame Retardant in Plastic Pallets

A Safer Alternatives Assessment

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Executive Summary

Maine has taken a leading role in moving to reduce public exposure to decabromodiphenyl ether (decaBDE), a potential endocrine disruptor and persistent toxic chemical used for decades as a flame retardant in a variety of consumer and other products. In 2007, Maine passed legislation banning sales or distribution of decaBDE-containing TVs, computers, mattresses and residential upholstered furniture.¹ In 2010, Maine's legislature amended the law to also mandate a phase-out of decaBDE as a flame retardant in shipping pallets as soon as practicable, and its replacement with "safer alternatives."² The law explains "safer alternative" as "a substitute process, product, material, chemical, strategy or any combination of these."³

This study is an assessment of safer alternatives to continued use of decaBDE as a flame retardant in plastic shipping pallets. The assessment evaluates the availability of non-halogenated flame retardants to replace decaBDE, their current use or potential effectiveness in making a flame retardant plastic pallet, some cost constraints that could affect the development or adoption of non-halogenated alternatives, and their potential human health and environmental impacts compared to decaBDE. The assessment also investigates the potential to reduce the need for flame retardant plastic pallets through replacement by non-plastic pallets, or by adoption of more stringent fire protection and management methods by warehouses, distribution centers or other sites handling groceries, consumer electronics or other commodities commonly moved or stored on plastic shipping pallets.

The Market for Plastic "Grocery" Pallets and Fire Protection Requirements

Shipping pallets come in a wide variety of shapes and sizes and are used for both storing and shipping a vast array of consumer goods and industrial products throughout the U.S. each day. The dominant pallet material continues to be wood, though the use of plastic is growing, particularly in the sector of greatest concern for this study: the 40" x 48" 'grocery' pallet used for shipping and storing most rapid-turnover consumer goods such as groceries, cleaners, consumer electronics and a host of other products. The grocery pallet market comprises two significantly separate marketplaces:

¹ 2007 Laws of Maine, c. 296, enacting 38 MRSA §§1609, sub-§§4 and 5.

² 2009 Laws of Maine, c. 610.

³ Subsection 14 of 38 MRSA, section 1609.

- Pallet purchases by end users for their own use within a single site or a group of sites (sometimes called ‘closed pool’ or ‘captive’ uses) controlled and managed by the user, who can ensure that pallet characteristics and warehouse management and fire protection systems are appropriately matched; and
- ‘Open-pool’ leasing of pallets by manufacturers and distributors sending products to warehouses for retail stores or other companies all over the country, where the fire protection and management systems of warehouses storing products on these pallets may vary widely.

While plastic pallets play an increasing role in both settings, it is their use in ‘open pool’ leasing that is of greatest importance in this assessment. The National Fire Protection Association (NFPA), the organization that sets most fire protection standards for communities in Maine and the rest of the country, believes the most commonly-used plastics – both in pallets and products – present a greater risk of more severe fires than wood. As a result, it requires that either warehouses storing products on plastic pallets install and implement more stringent fire protection and management systems, or that the plastic pallets include fire retardants that reduce the fire risk they pose to the level of risk posed by wood pallets. Plastic pallets in the open-pool leasing market have almost exclusively contained decaBDE as the flame retardant, and the effort to identify safer alternatives in this study focuses on that use.

More Stringent Fire Protection and Management Standards as a “Safer Alternative”

This report examines whether adoption of more stringent fire protection and management methods by warehouses and other sites handling plastic shipping pallets could eliminate the need for the use of flame retardants in those pallets. Our investigation shows that this solution, viable in ‘captive’ settings for pallet use, does not currently provide an adequate safer alternative for ‘open pool’ pallet use. ***While there are fire safety systems and management practices for warehouses and other shipping locations that can make the use of flame retardants for plastic pallets unnecessary, these are not universally available, and do not provide a comprehensive short-term, safer alternative to use of plastic pallets with flame retardants.***

The NFPA’s fire protection standards for warehouses specify sprinkler systems and best management practices for commodities, packaging and pallets that present the most severe fire risks. Warehouses that achieve these levels would provide sufficient fire protection for plastic pallets without flame retardants. Some new or modernized

warehouses are built entirely with the highest protection levels, and can purchase and use plastic pallets without flame retardants.

Many warehouses, however, especially older buildings, meet only minimum NFPA protection requirements. For these warehouses, general use of plastic pallets is only feasible if the pallets are flame retardant. The three open-pool leasing companies (iGPS, CHEP, PECO) moving rapid-turnover consumer products send pallets to warehouses all over the country, a significant proportion of which are not built to the highest standards. So the use of open-pool plastic pallets without flame retardants is not currently feasible as a safer alternative to the use of plastic pallets with decaBDE.

Non-halogenated Flame Retardants or Non-Plastic Pallets as a Safer Alternative to Replace Flame Retardant Plastic Pallets with DecaBDE

To assess whether safer alternative pallets could provide the services in the open-pool leasing market currently provided by flame retardant plastic pallets with decaBDE, DEP stipulated that this study compare the decaBDE plastic pallet both with flame retardant plastic pallets using non-halogenated flame retardants⁴ and “with pallets made of wood and other materials”⁵ that also serve ‘grocery’ pallet customers in the open-pool leasing market.

For a plastic pallet with a non-halogenated flame retardant to be included in the comparison, it must meet two minimum tests.

- *Flame retardance*: For plastic pallets in a warehouse to be subject only to the same fire protection requirements as a wood pallet, rather than the more severe restrictions generally placed on plastic pallets due to the higher fire risk they present, NFPA requires that the pallets demonstrate, “a fire hazard that is equal to or less than wood pallets and are listed as such.”⁶ While the NFPA standard does not specify what listings are acceptable, the NFPA Handbook⁷ identifies two large-scale fire testing protocols – the Underwriters Laboratory UL 2335 test or

⁴ DecaBDE is a halogenated flame retardant in that it contains molecules of bromine, one of five elements in the group of elements called halogens. Of the halogens, only bromine and chlorine are effective as flame retardants. Maine law at 38 MRSA §1696(14)(B)(2) prohibits a person subject to the sales ban on deca-containing pallets from replacing the decaBDE with another halogenated flame retardant.

⁵ Specifications of Work to Be Performed, Task 10.

⁶ National Fire Protection Association, *NFPA 13: Standard for the Installation of Sprinkler Systems*, 2010 edition, 5.6.2.6.

⁷ This provides commentary and explanation, but does not have the official standing of the NFPA standard.

the Factory Mutual FM 4996 test. These tests are expensive and complex and, as of December 2010, only two plastic pallets using non-halogenated flame retardants have passed either test.

- *Toxicity:* In order to avoid the risk that a plastic pallet might use a non-halogenated flame retardant with adverse human health and environmental impacts as severe as those of decaBDE, DEP required that, as part of this report, promising non-halogenated flame retardants be reviewed with the Green Screen hazard-based screening tool developed by Clean Production Action.⁸ The Green Screen assesses a wide range of chemical impacts and generates scores of 1 (avoid, chemical of high concern⁹), 2 (use but search for safer substitutes), 3 (use, but still opportunity for improvement) or 4 (safer chemical). Of the eight non-halogenated alternative flame retardants reviewed using the Green Screen for this report, only one received a score of 1; six received a score of 2; and one received a score of 4. To be acceptable as a safer alternative for this assessment, an alternative must at least receive a score of 2.

Using these criteria, two plastic pallets with safer alternative, non-halogenated flame retardants are now in production or on the market

The following are the two plastic pallets that meet these criteria:

- Rehrig Pacific Company's 40 x 48 pallet uses a magnesium hydroxide-based flame retardant that has passed the Green Screen requirement, and the pallet is listed under UL 2335.
- CHEP's 40 x 48 plastic pallet has passed both the FM 4996 and UL 2335 tests and went into production the first week of December 2010 using a proprietary, phosphorus-based flame retardant that has passed the Green Screen requirement.

While there is at least one more company with a non-halogenated flame retardant plastic pallet waiting large-scale fire testing, its flame retardant is proprietary.

Once a plastic pallet with a non-halogenated flame retardant has passed these hurdles, companies must examine whether the pallet can meet the strength, durability and other performance requirements for use in the open pool market. Experts contributing to this report noted that the challenge making it difficult to get pallets with alternative flame

⁸ <http://www.cleanproduction.org/Greenscreen.php>.

⁹ The score received by decaBDE.

retardants to market is one of balance: the more flame retardant the formulator has to add to the plastic polymer, the more the flame retardant may weaken the pallet's crucial performance parameters.

Almost two decades ago, the Grocery Manufacturers Association (GMA) spelled out 19 design and performance specifications for a grocery pallet. Many of these specifications are now mandatory for an open-pool pallet (e.g., that the pallet must be strong enough to hold 2,800 pounds in storage while on a rack that provides support on only two edges). This study provides a comparison of the iGPS decaBDE, the Rehrig Pacific Company pallet, the CHEP plastic pallet, and the CHEP and PECO wood pallets, against the GMA specifications.

To determine whether either of the plastic pallets with non-halogenated flame retardants or the two wood pallets would provide a "safer alternative" to continued use of plastic pallets with decaBDE, DEP established two alternative criteria for determining whether one or more of these pallets provides a "functionally equivalent" alternative to the decaBDE plastic pallet.

"For the purpose of the study, a pallet will be considered functionally equivalent if:

- The pallet meets the Grocery Industry Pallet Performance Specifications as set forth ... [in] the Recommendations on the Grocery Industry Pallet System, ... 1992 or is capable of being manufactured to meet those standards; or*
- The pallet currently is used by the grocery industry or other market sectors to ship the same types of good shipped on pallets containing decaBDE. "*¹⁰

Conclusions on "Functional Equivalence"

None of the four potential alternative pallets meets the "functional equivalence" standard under the GMA performance specification test, since none meets all of the GMA specifications.

- Both wood pallets and the CHEP plastic pallet are over 60 pounds, exceeding the "desired weight" limit of less than 50 pounds.

¹⁰ Task 12, DEP "Specifications of Work to Be Performed."

- The Rehrig Pacific Company pallet has a rack load capacity of 2,000 pounds, which does not meet the GMA standard of 2,800 pounds. (This pallet is sold directly to end-users who may not need the capability to carry such heavy loads).
- The bottom surface covering amount appears to be lower than the GMA-specified 60% for the iGPS pallet and both CHEP pallets, while the iGPS pallet, and possibly the CHEP wood pallet, meet the 85% coverage target for the top deck.

Without considering the ambiguous results from the surface coverage specifications, the failure of three of the pallets to meet the GMA weight limit, and of the fourth to meet the GMA rack-load strength specification means that, with respect to this criterion, none of the pallets provides a functional equivalent to the decaBDE pallet.

Under the second “functional equivalence” criterion (whether the pallet “is used by the grocery industry or other market sectors to ship the same types of good shipped on pallets containing decaBDE”), there is a functionally equivalent alternative to plastic pallets containing decaBDE.

The PECO and CHEP wood pallets are used currently by the grocery industry or other market sectors to ship the same types of goods that are shipped on pallets containing decaBDE. A third pallet, the new CHEP plastic pallet, which just went into production at the beginning of December 2010, has been designed for use in that market. It is too early to say whether or not it will be used by companies using open pool services to ship the same types of goods, but CHEP’s market position as the largest open pool pallet company certainly makes this plausible. As a plastic pallet with a non-halogenated flame retardant, it meets the goal of bringing a plastic pallet with a safer alternative flame retardant into the market. It will be some time before the extent of its potential role in the market will become clear. That will depend both on the attractiveness of the pallet in the market for groceries and other consumer goods commonly shipped on open-pool pallets, and on the extent to which CHEP promotes its use as an alternative to wood pallets as well as to the decaBDE plastic pallet. But the production of a plastic pallet with a non-halogenated flame retardant by the largest company in the open-pool pallet market seems to meet the intent of this criterion.

Structure of This Assessment

Assessments of safer alternatives to the use of toxic chemicals in products often focus primarily on the assessment of available chemical substitutes for the function served by the chemical to be replaced. This is both valuable and extremely important, and in

many cases may be the only route to a solution. The use of the Green Screen for this report provided just such an assessment of alternative chemicals that could be used as flame retardants. (See Chapter VI for a summary of other chemical assessment tools.)

But Maine DEP also designed this study to assess the safer, non-chemical alternatives that might be developed through a focus on the structure and operations of the industry. This is not always incorporated as a systematic component of the alternatives assessment. In particular, this study looked at fire protection systems and management methods that might provide alternatives. While, in the short term, the stock of older and less protected warehouses makes a solution based entirely on these factors insufficient, the design helped to broaden the perspective of the study to include ways in which environmental health and fire protection goals could converge in future planning.

Introduction

This Alternatives Assessment is a study of safer alternatives to decabromodiphenyl ether (decaBDE) as a flame retardant for plastic shipping pallets. The assessment evaluates the availability of other flame retardants, their potential effectiveness in making a flame retardant plastic pallet, some cost constraints that could affect their development or adoption, and their potential human health and environmental impacts compared to decaBDE. The assessment also investigates the potential to reduce the need for flame retardants in plastic pallets through adoption of more stringent fire protection and management methods by distribution centers and warehouses handling commodities such as groceries, beverages, consumer electronics and other rapid-turnover consumer commodities.

The central question Maine's Department of Environmental Protection (DEP) has set for this study is to determine if there are any functionally equivalent alternatives to the continued use of plastic pallets with decaBDE. Answering this question requires an overview of the services plastic and non-plastic pallets currently provide in the shipping market, the logistical organization of these services, and the current or potential availability of safer, alternative non-halogenated flame retardants that could replace decaBDE in plastic pallets. As part of this assessment, the study also explores some of the complexities and costs of developing a flame retardant plastic pallet based on non-halogenated flame retardants.

DecaBDE is an extensively used fire retardant found in a variety of plastic, electronic, textile, upholstery and building products. It is one of a class of brominated flame retardant (BFR) chemicals, the polybrominated diphenyl ethers (PBDEs), and one of three commercial formulations that served until a few years ago as effective and inexpensive flame retardants. There is increasing evidence of decaBDE's widespread environmental persistence, presence in breast milk and children's blood, and potential liver, thyroid, and neurodevelopmental toxicity, raising concerns about its human health and environmental effects. Maine and other government agencies have acted to reduce use of and exposure to decaBDE, as well as other PBDE compounds, by enacting laws that either prohibit or restrict its use.¹¹

¹¹ Maine Department of Environmental Protection and Maine Center for Disease Control reported to Maine's legislature in January 2007 that the decaBDE flame retardant "is a persistent, bioaccumulative and potentially toxic chemical.... The slow release of decaBDE from [consumer] products has led to widespread environmental contamination. Levels in human tissue, human breast milk and the food we eat are cause for concern." *Brominated Flame Retardants: Third Annual Report to the Maine Legislature*, January 2007, http://www.maine.gov/dep/rwm/publications/legislative_reports/pdf/finalrptjan07.pdf.

DecaBDE is a synthetic chemical that does not occur naturally in the environment. It is differentiated from other members of the chemical family of polybrominated diphenyl ethers (PBDEs) by having ten bromine atoms. Other members of the PBDE family with fewer bromine atoms, such as pentaBDE with five bromine atoms, are generally considered to have greater acute and chronic effects than decaBDE. Nonetheless, decaBDE itself is on the European Union's (EU) priority list of endocrine disruptors, and has been evaluated as having very high aquatic toxicity and persistence in the environment. Its major targets in humans are the liver, kidneys, spleen and fat.¹² In addition, there is evidence that decaBDE decomposes in the environment to the more toxic molecules containing fewer bromine atoms.¹³ Further, recent studies indicate that decaBDE is bioaccumulating in humans, suggesting the potential for increased health risks from continued exposure.¹⁴

In 2004, Maine's legislature banned sale or distribution of products containing the penta or octa PBDE congeners¹⁵ and declared its intention to reduce risks to the public from exposure to decaBDE, "by implementing risk management measures or by prohibiting the sale of products containing ... the deca mixture ... if a safer, nationally available alternative is identified."¹⁶ In 2007, Maine passed legislation banning sales or distribution of televisions and computers with housings containing decaBDE. At that time, most of the worldwide production of decaBDE was thought to be used in the plastic casings of TVs.¹⁷ Subsequently, at the end of 2009, the United States Environmental Protection Agency (USEPA) reached an agreement with the two U.S. manufacturers and the largest importer of decaBDE to eliminate its use in consumer products by the end of 2012 and to stop use entirely by the end of 2013.¹⁸

¹² See Appendix IX, Green Screen for decaBDE.

¹³ Alcock RE, Busby J., "[Risk migration and scientific advance: the case of flame-retardant compounds](https://doi.org/10.1111/j.1539-6924.2006.00739.x)". *Risk Anal.* **26** (2: 369–81), April 2006. doi:10.1111/j.1539-6924.2006.00739.x. PMID 16573627

¹⁴ Thuresson, K., Höglund, P., Hagmar, L., Sjödin, A., Bergman, Å., and Jakobsson, K. (2006).

Apparent half-lives of hepta- to decabrominated diphenyl ethers in human serum as determined in occupationally exposed workers. *Environ. Health Perspect.* 114:176-181.

¹⁵ Structurally similar chemicals with differing numbers of bromine atoms – penta (5 bromine atoms), octa (8), deca (10).

¹⁶ "An Act To Reduce Contamination of Breast Milk and the Environment from the Release of Brominated Chemicals in Consumer Products," 2003 Laws of Maine, Chapter 629, <http://www.legislature.maine.gov/ros/lom/LOM121st/14Pub601-650/Pub601-650-33.htm>. Also in 2004, the European Union banned the use of penta and octa PBDEs, and EPA reached an agreement with the sole US manufacturer to cease production by the end of that year.

¹⁷ The Maine law also banned the sale of mattresses, mattress pads and residential upholstered furniture containing decaBDE in anticipation of the adoption of federal flame retardancy standards for those products. DecaBDE is not known to be used in these products currently.

¹⁸ "An Act to Protect Pregnant Women and Children from Toxic Chemicals Released into the Home," Maine Public Law, Chapter 2H.P. 1167 – L.D. 1658, effective September 20, 2007. http://www.mainelegislature.org/legis/bills/bills_123rd/chapters/PUBLIC296.asp. US EPA,

Legislative Background for DecaBDE Phaseout in Plastic Shipping Pallets

Maine's 2007 law was intended to eliminate the major residential use of decaBDE in the state by phasing out its use in TV housings. The use of decaBDE in plastic shipping pallets is recent and was not covered by the legislation. In 2010, the Maine Legislature addressed this new decaBDE usage in "An Act to Clarify Maine's Phaseout of Polybrominated Diphenyl Ethers," (the Act).¹⁹

The new law stipulates:

- Effective January 1, 2012, no one can, "manufacture, sell or offer for sale or distribute for sale or use in the State a shipping pallet containing the deca mixture of polybrominated diphenyl ethers...."
- Effective immediately, no one can sell, distribute or use a product made from recycled shipping pallets containing decaBDE – with the sole exception of new shipping pallets made from recycled shipping pallets containing decaBDE.²⁰

The law includes some exemptions, both temporary and permanent, to the sales ban.

- A company may seek a temporary exemption, valid only until January 1, 2013, based on one of the following four findings:²¹
 - No "safer alternative" exists that meets the above (subsection 14) criteria.
 - A pallet with a proposed safer alternative fails to meet fire safety or relevant performance requirements.
 - Additional time is needed to test a pallet with a safer alternative against fire safety or performance requirements.
 - Additional time is needed to modify the manufacturing process to produce a pallet with a "safer alternative."
- A company may continue to distribute or use shipping pallets containing decaBDE after January 1, 2013, if manufactured before January 1, 2012.²²

"Polybrominated Diphenyl Ethers," <http://www.epa.gov/opptintr/pbde/>;
<http://www.buildinggreen.com/auth/article.cfm/2010/2/1/Industry-Agrees-to-Phase-Out-DecaBDE-Flame-Retardant/>; letter from Albemarle Corporation to Lisa Jackson, December 15, 2009,
www.epa.gov/oppt/existingchemicals/pubs/actionplans/Albemarle.DecaBDE.pdf.

¹⁹ 2009 Laws of Maine, Chapter 610 [herein PL2009, c.610], "An Act to Clarify Maine's Phaseout of Polybrominated Diphenyl Ethers."

<http://www.mainelegislature.org/legis/statutes/38/title38sec1609.html> &
http://www.legislature.maine.gov/legis/bills/bills_124th/chapters/PUBLIC610.asp

²⁰ See PL 2009, c. 610, § 2 enacting 38 MRSA §1609, sub-§5-A

http://www.legislature.maine.gov/legis/bills/bills_124th/chapters/PUBLIC610.asp

²¹ 38 Maine Revised Statutes § 1609, sub-§ 5-B.

http://www.legislature.maine.gov/legis/bills/bills_124th/chapters/PUBLIC610.asp

- A company may manufacture, sell, distribute or use shipping pallets after January 1, 2013 made from recycled shipping pallets containing deca.²³

Finding “Safer Alternatives”

A central feature of Maine’s law on decaBDE is the requirement to find a “safer alternative” to replace decaBDE’s role as a flame retardant. The legislation stresses both the practical need to find an alternative to decaBDE that is effective and commercially available, and to ensure that companies do not substitute alternative flame retardants with other serious toxicity problems.²⁴

For plastic shipping pallets, the 2010 law requires the replacement of decaBDE with a “safer alternative” (whether chemical, product or management strategy) that meets the following criteria:²⁵

- Reduces the “potential for harm to human health or the environment....” Any potential chemical alternative (or its breakdown products) must not be defined by USEPA as a persistent, bioaccumulative and toxic [PBT] chemical, and cannot be a brominated or chlorinated flame retardant.²⁶
- “Serves a functionally equivalent purpose” for fire safety and performance.
- “Is commercially available on a national basis.”
- “Is not cost prohibitive.”

Purpose of Alternatives Assessment Study for Use of DecaBDE in Plastic Shipping Pallets

Section 9 of the Act calls for an alternatives assessment study by the Department of Environmental Protection (DEP) to evaluate the availability of measures and alternatives for shifting from decaBDE to safer alternatives “as soon as practicable.”²⁷ The study must consider fire safety standards, tests and approvals as well as relevant performance specifications. DEP commissioned this study to assess two alternatives:

²² 38 MRSA section 1609, subsection 11 (A-1).

²³ 38 MRSA section 1609, subsection 5-A (B).

²⁴ In 2007, the Maine Department of Environmental Protection and Maine Center for Disease Control reported to the legislature that there were alternative flame retardants to replace decaBDE in the consumer products in which decaBDE was commonly used. *Brominated Flame Retardants: Third Annual Report to the Maine Legislature*, January 2007, <http://www.maine.gov/dep/rwm/publications/legislative-reports/pdf/finalrptjan07.pdf>.

²⁵ 38 MRSA Section 1609, subsection 14.

²⁶ A decaBDE replacement can include 0.1% of PBTs or brominated or chlorinated flame retardants, or 0.2% of a halogenated organic chemical containing fluorine. 38 MRSA Section 1609, subsection 14(B).

²⁷ Section 9, “An Act to Clarify Maine’s Phaseout of Polybrominated Diphenyl Ethers.”

- The availability of safer nonhalogenated alternative chemical flame retardants for plastic shipping pallets; and
- The potential for using best management practices in lieu of flame retardants to meet fire safety requirements.

With respect to the first of these alternatives, the goal of this report is to determine pallets with safer nonhalogenated alternative flame retardants are functionally equivalent to pallets containing decaBDE. Functional equivalence will be evaluated according to the following criteria established by DEP:

“For the purpose of the study, a pallet will be considered functionally equivalent if:

- *The pallet meets the Grocery Industry Pallet Performance Specifications as set forth on page 11 of the Recommendations on the Grocery Industry Pallet System, Cleveland Consulting Associates, 1992 or is capable of being manufactured to meet those standards; or*
- *The pallet currently is used by the grocery industry or other market sectors to ship the same types of good shipped on pallets containing decaBDE.”²⁸*

Preparation of This Report

Maine’s Department of Environmental Protection commissioned Pure Strategies, Inc.²⁹, a Massachusetts consulting firm that works with states, public interest groups and businesses on the sustainability and use of environmentally safer materials, to develop a report assessing whether functionally equivalent safer alternatives are available. Two firms with specialized expertise have supported this work and provided sections of the report. Flame Retardants Associates, Inc.³⁰, a company specializing in the field of specialty polymer additives, particularly flame retardants and smoke suppressants, wrote sections of the report and provided information on the range of available non-halogenated alternative flame retardants for decaBDE and the technical and economic challenges of their use in pallets. ToxServices³¹, a toxicology risk assessment consulting firm, prepared the Green Screens of the potential alternative flame retardants identified during this study and wrote the section of the report summarizing those results. ToxServices had previously supported the development of Clean Production Action’s Green Screen for the assessment of chemicals’ environmental and human health impacts. The sections of the report these two firms prepared are identified at the beginning of each section.

²⁸ DEP, “Specifications of Work to Be Performed” (as amended 10-13-10).

²⁹ <http://www.purestrategies.com>

³⁰ <http://www.flameretardantsconsultants.com/>

³¹ <http://www.toxservices.com/>

Chapter I: Plastic Shipping Pallets: Markets & Uses

Plastic Pallets as a Part of the Entire Shipping Pallets Market

Shipping pallets come in a wide variety of shapes and sizes, and are used both for storing and for shipping a vast array of consumer goods and industrial products throughout the United States each day. While estimates vary, most sources figure that approximately three billion pallets are in use in the U.S. Pallets are made of a variety of materials: wood, plastic, aluminum, steel, corrugated paperboard, and composite wood. The dominant pallet material is wood, with well over two billion of these in use, accounting for about 80% of the annual demand for new or repaired pallets. While much smaller in terms of the total pallet market, plastic is the second largest, and fastest growing, pallet material. Over 900 million plastic pallets are in use, and demand for plastic pallets is projected to increase by more than double the total annual pallet growth rate (2.4% vs. 1%) in the near future. A 2008 study³² estimated that by 2012 the total annual market for pallets could be 1.5 billion, of which 130 million would be plastic. Other pallet materials will play smaller or specialty roles.

Figure 1.1. Pallets made from wood, plastic, and metal



Wood Pallets



Plastic Pallet



Metal Pallet

As Table 1.1 illustrates, pallet size varies by market sector, depending on factors such as strength, weight, cost, durability, and the shipping or storage requirements of the

³² "Pallets: One Size Fits Nobody," Pacific Design & Manufacturing, September 1, 2008. http://mhlnews.com/transport-packaging/mhm_imp_6438/; "Plastic Pallets Gain Ground in an Eco-Conscious World," September 1, 2008. <http://www.thefreelibrary.com/Plastic+pallets+gain+ground+in+an+eco-conscious+world-a0185165596>; The Freedonia Group, *Industry Study: Pallets*, June 2008. Robert Bush and Philip Aranon, "Updated Pallet and Container Industry Production and Recycling Research," USDA-Forest Service, SRS 04-CA-11330142-205, October 2008.

specific sector.³³ The most common type of pallet is the 48x40 ‘grocery’ pallet (for rapid-turnover consumer products such as foods, laundry detergents, paper towels and many others), constituting about 30% of the total pallet market. This is the category where plastic pallets play their largest role, though wood pallets still predominate.

For assessing alternatives to using plastic pallets with decaBDE flame retardants, the uses and requirements for the 48x40 plastic pallet are the most important to consider. This is the pallet most frequently made with flame retardants (for reasons that will be discussed below), though flame retardant plastic pallets are still a minority of these pallets.

Table 1.1: Sizes and Uses of Pallets

Dimensions, inches (W × L)	Production Rank	Industries Using
48 × 40	1	Grocery, common in many other industries
42 × 42	2	Telecommunications, Paint
48 × 48	3	Drums
40 × 48	4	Department of Defense, Cement
48 × 42	5	Chemical, Beverage
40 × 40	6	Dairy
48 × 45	7	Automotive
44 × 44	8	Drums, Chemical
36 × 36	9	Beverage
48 × 36	10	Beverage, Shingles, Packaged Paper

Performance Standards for the ‘Grocery’ Pallet

In the early 1990s, the Grocery Manufacturers Association (GMA) published specifications designed to bring greater uniformity to the design and attributes of the 48x40 grocery pallet in order to ensure that pallets used for shipping grocery products would meet basic standards.³⁴ These standards focused both on ensuring that pallets would not create any risks for the transported foods and on facilitating the most efficient movement of goods between different companies.

³³ Table from: Clarke, John, “Pallets 101: Industry Overview and Wood, Plastic, Paper & Metal Options,” www.ista.org/forms/Pallets_101-Clarke_2004.pdf.

³⁴ See Grocery Industry Pallet Performance Specifications from “Recommendations on the Grocery Industry Pallet System” in Appendix II.

The GMA standards cover a number of areas:

- *Fire protection:* GMA pallets “must meet or exceed current pallet resistance to fire.”
- *Size and structure:* Pallets must be 48x40 inches; no more than 6 inches in height; have minimum 85% coverage on the (non-skid) top surface of the pallet; 60% coverage on the bottom surface; have ‘4-way entry’ (openings that allow forklifts and other equipment to lift the pallet from any direction); and meet other technical criteria to facilitate consistency with pallet management equipment.

Figure 1.2: Four-Way Entry Pallet



- *Weight:* Less than 50 pounds.
- *Sanitation:* Made of material that does not contaminate the product it carries.
- *Durability:* Capable of ‘multiple cycles.’
- *Strength:* Capable of holding 2800-pound loads both in racks (which provide support only for the edges of the pallets) and, on a flat surface, in stacks five loads high (each fully loaded with 2800 pounds).³⁵

³⁵ This latter standard has been superseded by an industry standard of 30,000 pounds.

Figure 1.3: Empty Racks Used for Pallet Storage



- *Recyclable:* Preferably made from recycled materials.
- *Repairable:* At reasonable cost.
- *Moisture and weather resistant.*

The GMA standard, while not formalized as a consensus standard through an organization such as the American National Standards Institute (ANSI), is widely referenced as a series of goals pallets should meet, especially pallets used for shipments between different companies (e.g., from a Kellogg's or Kraft manufacturing site to a grocery warehouse). Some of the criteria are clearly critical (e.g., 48x40, 4-way entry). But even for inter-company 'grocery' shipments there are some variances. For example, the standard requirement for the strength of stacked pallets is generally 30,000 pounds (rather than the 14,000 pound requirement for holding five 2800-pound loads), and the wood pallets that dominate in such pooled inter-company transfers generally weigh well over 50 pounds. In addition, many pallets are designed to meet more limited, specific purposes. But the GMA standards, and more recent technical performance standards, play an important role in efforts to develop plastic pallets with non-decaBDE flame retardants, since the flame retardants can have significant impacts on these other performance needs (see Chapter 3).

Some Different Types of Plastic 48x40 Pallets

Within the category of 48x40 plastic pallets used for shipping and storing food and consumer products, pallet users can choose from a variety of options depending on specific needs. The following are a few examples of plastic pallets serving different functions.

- **Rackable/stackable pallets:** These pallets are used for shipping products from manufacturers/producers to end-users, and for storing products on racks or in stacks in a warehouse or distribution center. While individual attributes (such as specific load-bearing capacity or whether the pallet is fire retardant) can vary depending on whether these pallets are used in a 'captive' system (e.g., controlled by a single company) or for rental/leasing use involving different companies, these pallets are designed for carrying or storing heavy loads. If used for shipping/storing products outside a closed-loop or captive system, these pallets should be capable of holding 2800-pounds when suspended between two beams of a warehouse storage rack (rackable) and up to a 30,000-pound static load supported by a solid platform (stackable).
- **Nestable pallets:** Light weight pallets (e.g., 20-30 lbs.) are generally used for moving products within a single warehouse or distribution center, between facilities within a single organization, or in a closed-loop between cooperating businesses, such as between a warehouse and the retail outlets of a single company. When not in use these pallets fit together (nest) to minimize storage space and shipping space. Because of their light weight, they can be handled more easily at end-user stores than any of the stronger rackable or stackable pallets. Correspondingly, they do not have the necessary load-bearing capacity to be used for such storage. They are not generally made with flame retardants. These pallets tend to be in fairly continuous use, but their nesting ability substantially reduces the stack heights required for temporary storage – an important benefit for compliance with fire prevention regulations (see below in Chapter II).

Rackable/Stackable Plastic Pallet



Manufacturer: Schoeller Arca

Nestable Plastic Pallet



Manufactured by Rehrig-Pacific

- *One-way/international pallets:* When sending products overseas by air, shippers may have little expectation of seeing the pallets returned. Shippers also want to avoid paying high air freight costs for heavy shipping pallets. One option is to use very light pallets (12-19 pounds) specially designed for international air travel, and possibly, one-way use. These pallets have limited load capacity, and could not be used for racking or stacking products.

What Criteria Drive Pallet Selection?

International/One-Way Plastic Pallet



Manufactured by CABKA

There is a wide range of options available to the logistics, operations and warehouse managers who make purchasing decisions on pallets, both generally and for the 48x40 'grocery' pallets that principally concern us with respect to fire prevention and flame retardants. A recent survey of such managers by Modern Materials Handling (MMH) indicates that individual facilities may make different selections for different purposes. For example, the survey results demonstrated a significant percentage of mixed purchasing of wood, plastic or other types of pallets based on diverse needs within single operations (Table 1.2).³⁶

Table 1.2: Purchasing Patterns

Pallet Material	% Purchasing Pallets Made of Each Material (may buy multiple types)
Wood	92%
Plastic	33%
Engineered wood (e.g., plywood)	15%
Cardboard/corrugated	10%
Metal	6%
Other	3%

The MMH survey also asked respondents what factors were most influential for them when they were making decisions to buy either plastic or wood pallets. Not surprisingly, cost is important when choosing either plastic or wood.

³⁶ "Pallet Usage and Trending Study," *Modern Materials Handling*, October 28, 2010.

Table 1.3: Survey Respondents' Reasons for Selecting Plastic or Wood Pallets³⁷

Attribute "very important"	When Selecting Plastic Pallets - %	When Selecting Wood Pallets - %
Purchase price	61	70
Durability	58	49
Strength	57	56
Cost per use	55	52
Reusability	53	34
Availability	42	54
Easy to clean	38	20
Recyclability	32	25
Weight	31	21
Design versatility	26	16
Ease of disposal	24	17
Fire rating	19	11
Ease of repair	15	19

Not only is cost the factor most frequently cited for selecting both plastic and wood pallets, but some of the other factors, such as durability and reusability, are directly or indirectly related to cost as well. If a manufacturer is sending pallets it purchases overseas, or domestically to locations from which it is unlikely to recover the pallets, then the lowest cost pallet that will hold up in transit is important (or, alternatively, with large volumes, pooling may be the best way to reduce costs). If pallets will be in a captive system where they are used only between different facilities from the same company (e.g., between Hannaford's warehouse and Hannaford stores), then higher-priced durable pallets may be the lower-cost, long-term option. There are also some differences in reasons for selection of wood or plastic, such as a greater emphasis on availability in selecting wood or on weight (for fuel efficiency or reduced worker injuries) in selecting plastic.

Buying or Renting/Leasing Pallets

In addition to deciding whether to use pallets of wood, plastic or other materials, companies also can choose either to buy pallets directly for their own use, or to rent or lease pallets that are managed and repaired by companies that specialize in pallet

³⁷ Respondents were not limited to a single response. In many cases a facility or company might buy both plastic and wood pallets for different purposes. The survey also has an "important" category, but the same 6 attributes remain highest in importance when 'very important' and 'important' responses are added. "Pallet Usage and Trending Study," *Modern Materials Handling*, October 28, 2010.

management. A warehouse or logistics manager who decides to out-source pallet management can lease pallets with delivery and repair contracts to meet its needs, or can turn to companies that provide ‘open-pooling’ pallet management/rental systems (see below).³⁸

Whether a company chooses to buy pallets or to participate in a pallet rental or open-pooling system depends to a significant extent on how the pallets will be used. For example, a company using pallets only for internal warehouse storage and movement, or for moving goods between its own facilities is more likely to purchase and manage the pallets it uses, while a company sending goods on a routine basis to a variety of buyers all over the country stands to benefit more from a rental service.

Overall, companies buy and self-manage far more pallets than they rent. Only a third of managers responding to the MMH survey reported making use of pallet retrieval, recovery or rental systems, and slightly more than 10% specifically reported using pallet rental services. In the universe of 48x40 grocery pallets, the three major, open-pooling rental companies manage approximately 90 million pallets – approximately 10% of the total number of 48x40 pallets in use.³⁹

Open-Pool Pallet Leasing

Open-pooling of pallets is more important – both commercially and for the search for alternatives to the use of decaBDE – than the numbers above suggest.

- Open-pool ‘grocery’ pallets move relatively rapidly in commerce, as that is how the open-pooling companies make their money.
- Many of the largest companies in high-turnover, consumer products – from manufacturers to retailers – use open pooling services.
- Open-pooling of pallets is growing.
- While a relatively small percentage of plastic pallets sold directly to users are made with flame retardants, virtually all plastic pallets in open-pooling systems are made with flame retardants.

³⁸There are also ‘closed loop’ pallet systems where one or more companies move products on their own pallets from manufacturing or distribution centers to stores or regional warehouses, and then return those pallets for reuse. Smaller companies may share pallet purchasing, management and/or repair systems for increased efficiency such as for sharing truckloads of goods.

³⁹ According to data reported by MMH, the three largest open-pooling companies use between 80-90 million pallets, while the total universe of 48x40 pallets (approximately 30% of 3 billion total pallets) is about 900 million. See articles on CHEP, iGPS and PECO in the October 6, 2010 issue of MMH magazine: http://www.mmh.com/article/pallets_and_containers_the_plastic_pool_alternative/, http://www.mmh.com/article/pallets_and_containers_a_chep_off_the_old_block/, http://www.mmh.com/article/pallets_pallet_pooling_for_the_other_guys/.

While a small proportion of the total shipping pallet universe, open pooling of pallets plays a major role in shipping consumer goods from manufacturers or food producers to distribution centers and warehouses for wholesalers and retailers. Large national companies such as Kellogg's, SC Johnson, Kraft Foods Inc., and Pepsi, use open-pooled pallet systems to distribute their products to hundreds of retail distribution centers and grocery warehouses around the country.

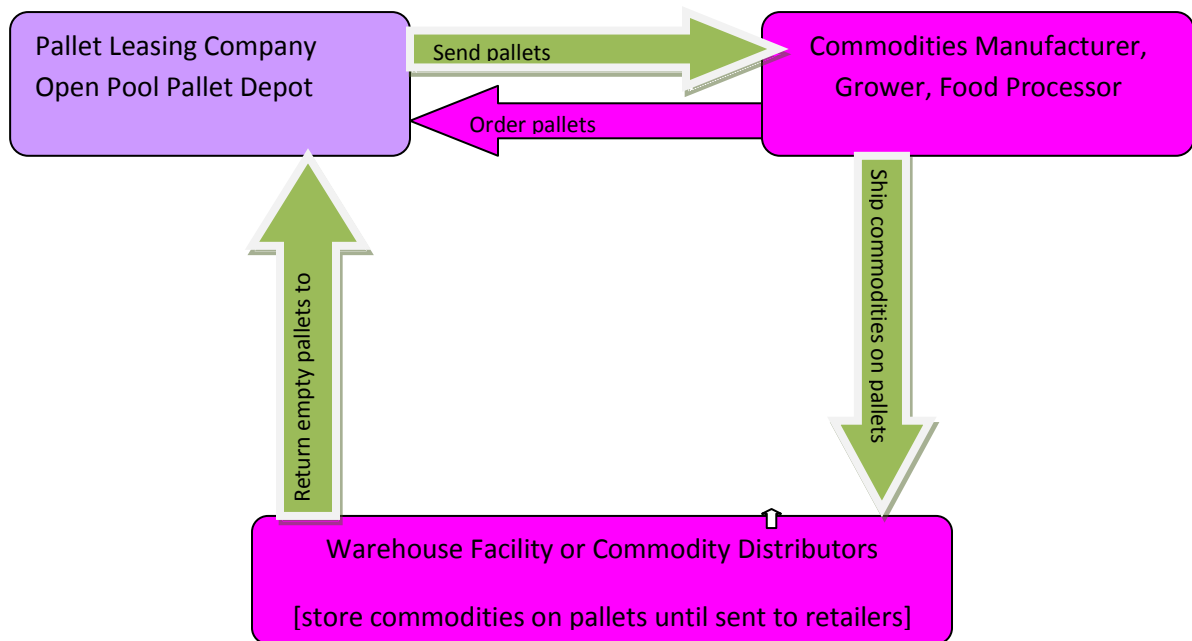
There are three major open-pooled pallet management companies in the U.S. that provide this service – CHEP, Intelligent Global Pooling Systems (iGPS), and PECO Pallet (PECO)⁴⁰. CHEP is the goliath of the business, with approximately 65 million pallets in use. Originally it was the only major player, but both iGPS (approximately 10 million pallets) and PECO (5 million pallets) have emerged during the last decade. CHEP and PECO both provide wood pallets (though CHEP has a very small number of plastic pallets, and just began manufacture of a new plastic pallet at the beginning of December 2010). iGPS has broken into the market with a plastic pallet, clearly differentiating itself from CHEP. All of these pallets are 48x40 pallets used for groceries and other rapid turnover consumer goods.

How open pooling works

Figures 1.4 and 1.5 below provide a schematic overview of how open pooling systems work. Figure 1.4 illustrates the basic process:

⁴⁰ See articles on CHEP, iGPS and PECO in October 6, 2010 issue of MMH:
http://www.mmh.com/article/pallets_and_containers_the_plastic_pool_alternative/,
http://www.mmh.com/article/pallets_and_containers_a_chep_off_the_old_block/,
http://www.mmh.com/article/pallets_pallet_pooling_for_the_other_guys/.

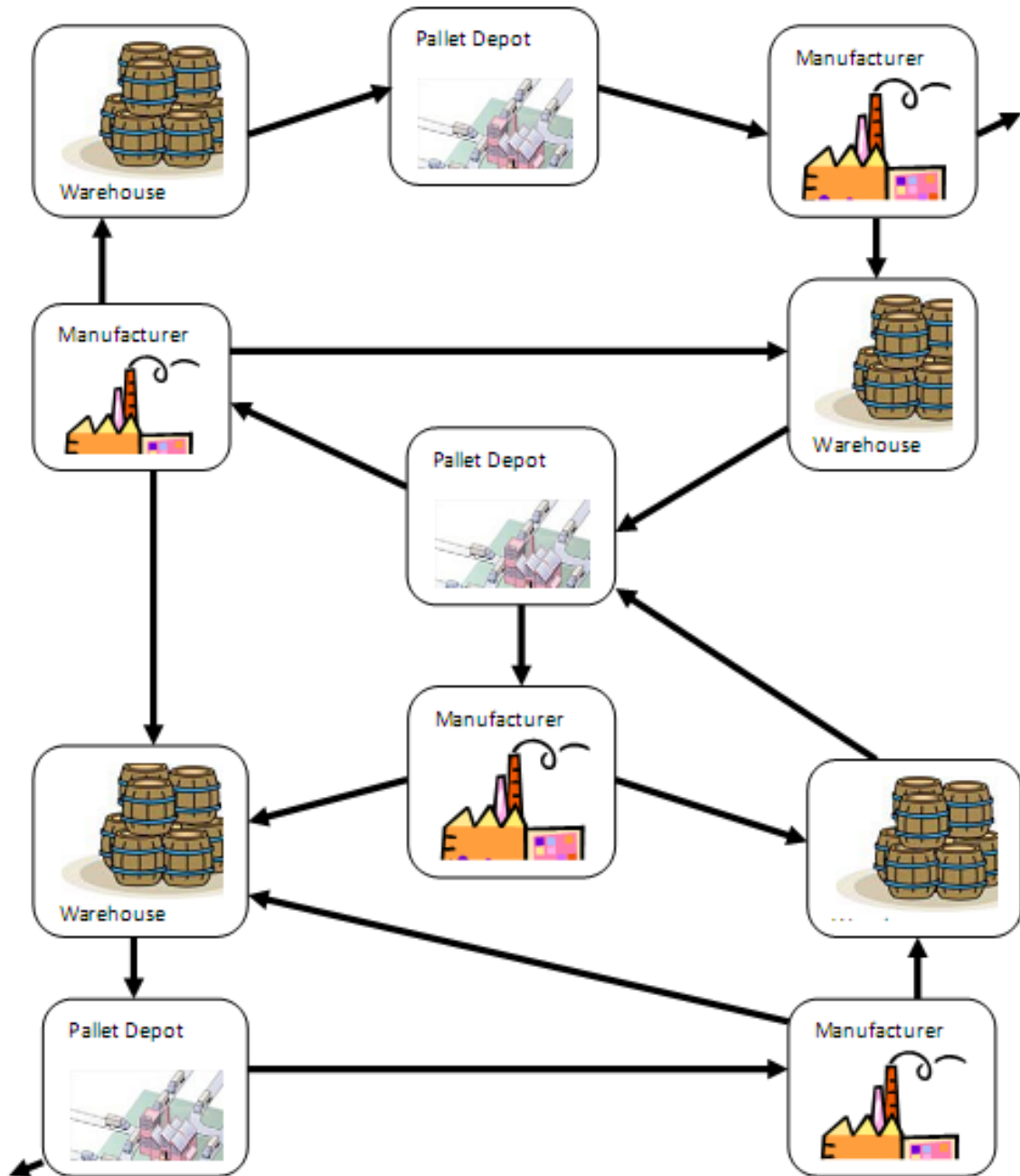
Figure 1.4: Schematic of Open-Pool Pallet Leasing



- A company with an agreement with an open pooling company (CHEP, iGPS or PECO) sends an order for a truckload or more of pallets for one of its manufacturing/production centers.
- The open-pooling company sends the pallets from one of its pallet depots to the manufacturer.
- The manufacturer loads the pallets and sends them to a variety of different warehouses or customer distribution centers around the country.
- The pallets may be unloaded immediately or used for some time for storage of commodities until ready for redistribution to retail stores, restaurants, hospitals, etc.
- Once unloaded, the pallets are stored at the warehouse until a truckload of pallets is ready for collection by the pooling company which returns them to a nearby pallet depot.
- At the depot, pallets will be cleaned, repaired, recycled or replaced as necessary.
- The process is repeated.

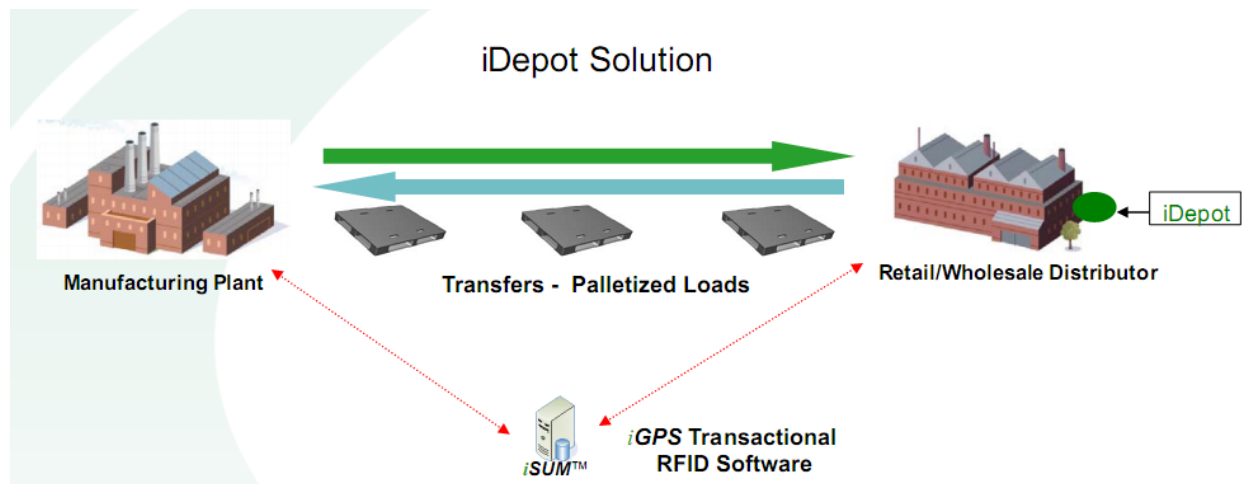
Figure 1.5 illustrates that the pooling system is ‘open,’ as the same pallet may go to a different user each time. The pallet moves from depot to manufacturer to warehouse (or, occasionally, retail store) to another depot, and then another manufacturer, another warehouse, etc., as it is leased to different users for shipping their products.

Figure 1.5: Movements of Pallets between Various Users in Open Pooling



The key to profitability for CHEP, iGPS and PECO is for their pallets be in constant use, and to ensure that pallets are effectively tracked so that as few pallets as possible are lost. While all three companies have systems to keep track of their pallets, iGPS uses a radio frequency identification (RFID) tracking system that iGPS believes makes it possible to cut a step out of the pallet cycle. iGPS has agreements with some warehouses that receive merchandise on iGPS pallets to check and clean the pallets at the warehouses so they can be sent directly to the next user without going back to an iGPS pallet depot (Figure 1.6).⁴¹

Figure 1.6: Open Pooling without Returning Pallet to Depot



How Do Facilities/Companies Use Pallets?

An important factor in deciding whether to purchase pallets or use a pallet rental service is the anticipated use of the pallets. As the following information from the MMH survey demonstrates,⁴² most operations have multiple uses, and may use different pallets for different purposes.

⁴¹ Information from Lew Taffer, iGPS, October 4, 2010. Figure 1.6 provided by Lew Taffer.

⁴² "Pallet Usage and Trending Study," *Modern Materials Handling*, October 28, 2010.

Table 1.4: How Companies/Facilities Using Pallets
(Companies may use pallets for more than one purpose)

How Pallets are Used in Operations	%
Within a facility	76
One-way between trading partners	65
Between company facilities	55
When exporting	38
Closed-loop between trading partners	23
Other	5

There are many variations in how pallets may be used, from limited internal movement of materials within a manufacturing center to a variety of movements between facilities of the same or different companies. The following examples illustrate some of the options:

- Hannaford warehouse in South Portland, Maine:* The Hannaford warehouse receives a vast array of groceries, beverages, cleaners, and other consumer products from major companies and distributors, and re-distributes them to Hannaford stores throughout New England. Inbound products come in on both wood (predominantly) and plastic pallets, including pallets from the three major open-pooling companies, and some additional white wood pallets and occasionally other types of pallets. The goods arriving on the pooled pallets or those of higher quality white wood are stored on those pallets on racks until ready for re-distribution to stores. These pallets weigh from slightly less than 50 pounds for plastic up to 65 or 70 pounds for wood. The goods and their pallets are moved by forklift or mechanized systems. After the products are removed from the pallets for shipment to individual Hannaford stores, the empty pallets are stored until a truckload of pallets is ready for pickup by the appropriate company.

To send products to individual Hannaford stores, an appropriate mix of products is placed on light-weight (less than 30-pound) “nestable” plastic pallets that, while not strong enough to use for storing products in racks, are easier for store personnel to handle. Once empty, these nestable pallets are returned from Hannaford stores to the Hannaford warehouse.⁴³

⁴³ Personal communication from Al Hussey, Manager, Hannaford warehouse, South Portland, Maine, September 13, 2010.

- *Sysco of New England, warehouse in Westbrook, Maine:* Inbound freight for the Sysco warehouse usually arrives on wood (95% on CHEP pallets and the rest on inexpensive white wood pallets) and is stored in the warehouse largely on the CHEP pallets. To send products from the warehouse to customers, Sysco moves the goods onto lightweight nestable plastic pallets. None of these contain flame retardants. The warehouse buys the plastic pallets from Rehrig Pacific Company at a cost ranging from \$28-33, depending on the crude oil price.

The plastic pallets are a substantial cost to the warehouse, but the warehouse chose them for two reasons. The first concerns sanitation; the plastic pallets can be washed, whereas wood can harbor spills and bacteria, and is frowned on by food safety auditors. The second reason is convenience. Once pallets going to stores are unloaded, empty pallets can be stored on the truck as it moves to the next store and plastic pallets can be strapped to the sides of trucks to make easier unloading at subsequent stores. Wood pallets are too heavy for this and must be left on the truck floor where they may be in the way.

For the most part, the plastic pallets go to customers, are unloaded and then returned. But the warehouse has had problems with high attrition rates (eight years ago, as high as 30%/year), largely due to drivers leaving pallets with customers. Driver training, stressing the expense to the company, has reduced the loss ratio to as little as 5%/year. Because of the cost factor, Sysco now ships to stores on Maine's coastal islands on cheap wood pallets, because the pallets sent there rarely come back.⁴⁴

- *Sunny Delight Beverages Co. (Sunny Delight):* Sunny Delight primarily uses open pooled pallets for sending products to its customers, and recently shifted to iGPS plastic pallets. Two major factors led to Sunny Delight's decision to switch from wood pallets to plastic pallets – both related to cost. As beverage products are relatively heavy, lightening the total load by reducing pallet weight represents a significant potential savings in fuel use. Second, the use of RFID tracking of the iGPS pallets allows integrated control of data on inventory and deliveries with automated reconciliation on pallet use. This system could potentially allow fully automated warehouse operations – with possible major long-term cost savings. While Sunny Delight had heard concerns that the presence of decaBDE could impair their products, the industrial hygiene firm

⁴⁴ Personal communication from David Thomason, VP, Operations, Sysco of Northern New England, October 26, 2010.

they hired to do assessments found no air or dust issues. While it uses pooled plastic pallets wherever possible, Sunny Delight uses heat-treated wood pallets for deliveries to the Caribbean and Mexico, due to the difficulties of retrieving pallets delivered to locations in those regions.⁴⁵

- *Kellogg's*: Kellogg's primarily uses wood pallets. These include both open pooled pallets (CHEP) for large commercial customers and some white wood for deliveries to smaller customers. The company is working to convert its entire network to pooled pallets. Externally, customers are major drivers in the choice of pallet for deliveries. Internally, Kellogg's has some captive pallets for moving items around in production facilities; mostly these are white wood pallets, though there are a few nestable plastic pallets (for which Kellogg's gets about 32 cycles before sending them in for reforming). For international shipments, Kellogg's uses heat-treated wood pallets to meet international phytosanitary standards.

While they are generally happy with wood pallets, there have been some issues. One concern was the potential impact of having wood pallets in the production area; Kellogg's doesn't want pieces of wood where food is processed. They solved this by bringing wood pallets to the outskirts of the production area and loading products on the pallets as ready-to-ship products. Another potential consideration has been the weight of the wood pallets. This is not so much an issue for shipping cost, because Kellogg's products are very light. It is more an ergonomics issue for workers. To avoid any adverse effects, Kellogg's uses equipment – such as forklifts and pallet dispensers -- for handling the pallets.⁴⁶

Pooling & Purchase: Separate Markets

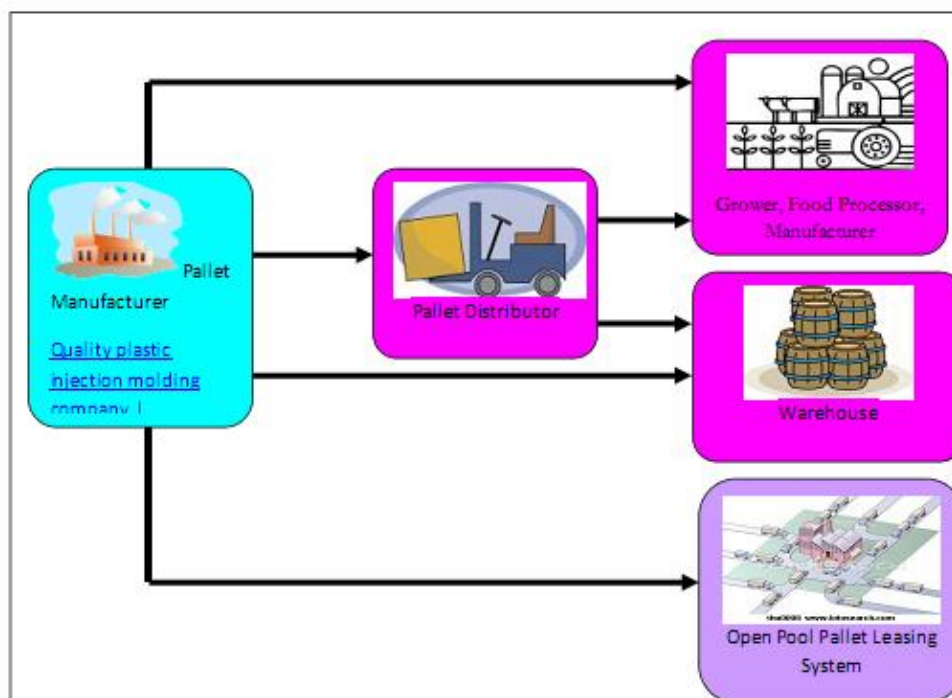
As these examples illustrate, the markets for pallet purchasing and pallet pooling are, to a significant degree, distinct. A company's internal (captive) operations involving movement within or between facilities or infrequent or small one-way shipments are far more likely to involve pallet purchases than open pooling. Pallet manufacturers focusing on this market can sell directly to large captive operations, or sell to distributors who market pallets to smaller buyers.

⁴⁵ Personal communication from Keith Singleton, Logistics Manager, Sunny Delight, October 29, 2010.

⁴⁶ Personal communication from Linda Maupin, Director, Foreign Trade and Distribution Services, Kelloggs, November 16, 2010.

For the hundreds of companies shipping to widely diverse buyers all over the country such as grocery chains and mass merchandising stores, open pooled pallet shipping arrangements are an ideal way to outsource logistical challenges. The differences between these two markets are important for considering the safer alternatives to continued use of decaBDE as a flame retardant in plastic pallets.

Figure 1.7: Markets for Pallets



Plastic Pallet Manufacturers

While plastic pallet manufacturers sell flame retardant pallets directly to end users, flame retardant pallets constitute a relatively small part of the direct sales market for plastic pallets.⁴⁷ The largest buyer of flame retardant plastic pallets is the open-pooling pallet company, iGPS. Pallets for iGPS are made by the manufacturer Schoeller Arca

⁴⁷ For example, only approximately 5% of the plastic pallets that Orbis sells are made with flame retardants. Personal communication from Curt Most, Orbis, September 21, 2010.

Systems. A number of other companies make flame retardant pallets for the open market, and a manufacturer has begun making flame retardant pallets for CHEP during the 4th quarter of 2010.⁴⁸

Table 1.5 provides information on major manufacturers of plastic pallets for the U.S. market. Pure Strategies has identified 19 manufacturers and 62 distributors⁴⁹ of various types of plastic pallets. Pallet manufacturers are plastic molders. Manufacturing pallets requires investment in large, technically complex and very expensive equipment. Once a mold is fabricated to make a part, the manufacturer must sell a lot of parts to pay for the equipment. So, unlike the market for making wood pallets that involves a large number of small companies as well as major producers, plastic manufacturers must be relatively well-capitalized and technically sophisticated. Table 1.5 identifies: manufacturers; the type of plastic produced (e.g., polypropylene (PP), high density polyethylene (HDPE)); whether or not the manufacturer offers a pallet with flame retardant; available information on the type of flame retardant now in use; and available information on efforts by the manufacturer to develop a pallet using a flame retardant other than decaBDE. As Table 5 shows, only seven manufacturers are currently marketing flame retardant plastic pallets and two companies are distributing flame retardant pallets through the open-pool leasing system.

Table 1.5: Plastic Pallet Manufacturers⁵⁰

Manufacturer	Pallet Types	Polymer Type ⁵¹	Flame Retardants Currently in Pallets	Status of Development of Pallet with Alternative Flame Retardant
CABKA North America	Rackable/ Stackable Nestable	Recycled PE & HDPE	None	
Decade Products	Rackable/ Nestable	Recycled HDPE	None	
The Fabri-Form Company	Nestable	HDPE	None	
Greystone Logistics	Rackable/ Stackable Nestable	Recycled plastic	None	
Craemer	Rackable	HDPE	None	

⁴⁸ CHEP has not yet publicly identified this manufacturer.

⁴⁹ See Appendix I

⁵⁰ Personal communications with Bruce Torrey, iGPS on 8/17/2010; Curt Most, ORBIS on 9/21/2010; Amy Lander, Rehrig Pacific on 9/7/2010; Debbie Bergen, TMF on 9/7/2010. Industry Study 2359 "Pallets" by the Fredonia Group (2008).

⁵¹ Abbreviations: polypropylene (PP); polyethylene (PE); high density polyethylene (HDPE); and polyvinyl chloride (PVC)

Manufacturer	Pallet Types	Polymer Type ⁵¹	Flame Retardants Currently in Pallets	Status of Development of Pallet with Alternative Flame Retardant
Mauser Holding GmbH	No data	Recycled PE	None	
Buckhorn (Meyers Industries)	Rackable/ Stackable Nestable	HDPE	None	
ORBIS	Rackable/ Stackable Nestable	PE	Some with flame retardants: DecaBDE Sb ₂ O ₃ ⁵²	Currently developing alternative
PDQ Plastics	Nestable	HDPE	None	
Plastics Research Corporation	Rackable	No information	No information	
Polymer Pallets	No data	PVC	No information	
Polymer Solutions International	Rackable/ Stackable Nestable	HDPE	DecaBDE	
Rehrig Pacific Company	Rackable/ Nestable	PP	Some with flame retardants: Magnesium hydroxide, aluminum trihydroxide, zinc borate	
Rotonics Manufacturing, Inc. (Stratis Pallets)	Rackable/ Nestable	PE	None	
Schoeller Arca Systems	Rackable/ Stackable	HDPE	Sb ₂ O ₃	Currently developing alternative
Shan Industries (Thermodynamics Division)	Rackable/ Nestable	PE	None	
TMF Corporation	Rackable	PE	Some with flame retardants: DecaBDE Sb ₂ O ₃	Currently developing alternative
TriEnda, LLC	Nestable	PE	None	
TranPak	Rackable/ Stackable	No information available	None	
Eco-Tech	Rackable	Recycled PVC plastic	None	
Manufacturer of CHEP pallet	Rackable/ Stackable	PP/ HDPE	Proprietary, phosphorus-based	

A relatively small percentage of plastic pallet manufacturers have produced and marketed flame retardant pallets. For those few, decaBDE has played a major role. But several efforts are now underway to develop alternatives. In addition, as the table makes clear, there is a substantial

⁵² Decabromodiphenyl ether is almost always used in combination with antimony trioxide.

market for plastic pallets without flame retardants. The following chapters will explore the implications of these patterns for finding a safer alternative to use of decaBDE as a flame retardant.

Chapter II: Fire Prevention Concerns and Requirements for Plastic Pallets

The National Fire Protection Association (NFPA) establishes the standard, NFPA 13,⁵³ that provides the basis for most state and local fire prevention laws and regulations governing warehouse construction and management throughout the country, although state or local requirements may sometimes be more stringent. The NFPA 13 standard includes requirements for management of shipping pallets in warehouses, including requirements that mandate stricter management controls and fire prevention systems for plastic pallets than for wood pallets. For plastic pallets, NFPA 13 provides two options: imposition of more stringent requirements on the warehouse for managing plastic pallets than for managing wood pallets, or use of plastic pallets that have passed tests demonstrating, “a fire hazard that is equal to or less than wood pallets and are listed as such.”⁵⁴ Use of the flame retardant decaBDE has allowed production of plastic pallets that pass the tests for equivalence to wood.

Finding a safer alternative to the use of decaBDE in plastic pallets requires pursuing one of the following options:

- Implement comprehensive warehouse fire prevention management practices and systems that make it safe to use plastic pallets that are not made with flame retardants
- Develop pallets with alternative safer flame retardants that are effective enough to enable the plastic pallets to be listed as equivalent to wood.⁵⁵

This Chapter reviews the NFPA rules governing these options and their application to warehouse management in Maine.

Pallets & Warehouse Fire Risk

Warehouse fires cause significant property loss every year, as well as creating a risk for loss of life. A NFPA summary of U.S. data for 2003-2006 reports an average of 1,350

⁵³ National Fire Protection Association, *NFPA 13: Standard for the Installation of Sprinkler Systems*, 2010 edition. NFPA uses a consensus process approved by the American National Standards Institute (ANSI) to develop its standards.

⁵⁴ NFPA 13, Section 5.6.2.6

⁵⁵ Another option for meeting the equivalence test includes use of inherently flame-retardant polymers for making a plastic pallet. While a review of this option lies outside the scope defined for this study, the costs of such polymers currently appear prohibitive for application in pallets, with the exception of polyvinyl chloride (PVC). PVC subjected to combustion temperatures decomposes into a variety of highly toxic chemicals including dioxins.

fires in warehouses each year during that period, with annual average losses of \$124 million in property and five deaths.⁵⁶ While most warehouse fires involve a mix of commodities, packaging, pallets on which the commodities are stored and, in some cases, stacks of pallets not currently in use (“idle” pallets), there are some cases of fires principally involving or caused by pallets – both wood and plastic.

- A National Institute of Standards and Technology (NIST) report in 2000 includes discussion of a warehouse fire in Japan five years earlier in which plastic pallets were stored for use with noncombustible commodities. Although the warehouse had automatic sprinklers that activated after the fire began, the fire overwhelmed the system, lasted 18 hours, and resulted in the deaths of three firemen. The Japanese fire agency concluded that adequate protection against future fires would have to include both an enhanced sprinkler system and a requirement for the use of flame retardants with plastic pallets.⁵⁷
- In September of 2010, a fire in Buffalo, New York at the warehouse of a wood pallet company took hours to control and destroyed the warehouse at a cost exceeding \$4 million. “Fire officials say the fire was fueled by wooden and plastic pallets as well as propane tanks stored in the building.”⁵⁸

According to an NFPA report, a variety of causes can contribute to starting warehouse fires. This covers direct causes, such as the ignition source that starts the fire, as well as inadequate warehouse management practices. The latter include things as simple as housekeeping to prevent piling up of wood splinters, dust or plastic wrapping. In terms of the direct sources of ignition, NFPA’s data for the 2003-2006 period shows the following are the most frequent causes of warehouse fires:⁵⁹

- 14% - Electrical distribution or lighting
- 13% - Intentional
- 11% - Confined trash or rubbish
- 10% - Heating equipment
- 7% - Vehicles

⁵⁶ Marty Ahrens, NFPA, “Structure Fires in Warehouses (Excluding Cold Storage) Fact Sheet,” February 2009. www.nfpa.org/assets/files/PDF/WarehouseFactSheet.pdf

⁵⁷ “Flammability Test for Flame Retardant Plastic Pallet” by Tokiyoshi Yamada, National Research Institute of Fire and Disaster, and Masahiro Sagara, Japan Pallet Association, in National Institutes of Standards and Technology, U.S. Department of Commerce, *Fifteenth Meeting of the UJNR Panel on Fire Research and Safety*, March 1-7, 2000, Volume 1, p. 89.

⁵⁸ “Fire damage at NY pallet company warehouse is \$4M,” *Palm Beach Post News*, September 10, 2010. <http://www.palmbeachpost.com/news/nation/fire-damage-at-ny-pallet-company-warehouse-is-907715.html>

⁵⁹ Marty Ahrens, NFPA, op.cit.

- 7% - Burners/soldering irons

Once a fire starts, preventing it from leading to catastrophic destruction depends on: the fuel provided by commodities, packaging and pallets; the design and management of storage; and the adequacy of the warehouse's sprinkler control system.

Increased Level of Fire Risks from Plastic Pallets

For shipping pallets, NFPA 13 addresses two sets of potential problems: the risk from fires involving palletized commodities, and the risks from fires involving "idle" pallets. In both cases the standards for plastic pallets are more stringent than those for wood pallets, with the exception noted above for pallets with fire risks equivalent to those for wood. Given both the predominance of wood pallets and the historical emergence of the fire protection rules when alternatives to wood pallets were rare, NFPA 13 treats wood pallets as the base case for the fire protection standards.

Most woods ignite more readily than the plastics, as shown in the table below. The flash-ignition temperature is the temperature at which a spark will cause the materials to catch fire.⁶⁰

Table 2.1

Polymer	Flash-ignition Temperature (°C)
Polyethylene	340
Polypropylene	320
Wood (various)	190-260

NFPA treats plastic pallets (or commodities) as a higher risk because, once a fire begins, a fire fueled by plastics becomes more difficult to suppress. The following table shows the comparative heat release factors for some of the plastics and woods used in shipping pallets. The numbers show that the plastics burn at higher temperatures and

⁶⁰ F. Laoutid et al, "New prospects in flame retardant polymer materials: from fundamentals to nanocomposites," *Materials Science and Engineering*, vol. 3, #3, January 2009, Table 1; Tony Café, "Physical Constants for Investigators," T.C. Forensics, Table 2.1, <http://www.tcforensic.com.au/docs/article10.html#2.1.2>; page updated 2007; Mark Diitenberger, "Ignitability of Materials in Transitional Heating Regimes," FAA, Thermal Analysis of Polymer Flammability (FAA Table 4), DOT/FAA/AR-07. Auto-ignition temperatures are the temperatures at which materials will catch fire spontaneously without a spark. These temperatures are somewhat higher: 350 °C for both polypropylene and polyethylene, and 300 °C generally for wood, though these temperatures can vary with the type or condition of wood (e.g., the auto-ignition temperature for dry red oak is 482 °C). http://www.engineeringtoolbox.com/fuels-ignition-temperatures-d_171.html

thus release more heat than any of the woods. There are differences between the softwoods and hardwoods, and some discrepancies in the figures for heat released by pine wood according to different sources, but all of the values for the woods are substantially lower than those for the plastics.

Table 2.2⁶¹

Heat Release of Some Plastics/Woods Used in Shipping Pallets

Polymer	ASTM D 2015 (MJ/kg) ⁶²
Polyethylene	43.3
Polypropylene	42.7
Pine wood ⁶³	18.5
Pine, red	12.9
Pine, white – Southern	13.6
Maple, hard	11.7
Oak, red	11.4

As plastic has become an increasingly large fraction of warehouse contents, studies and experience have shown that fires involving high proportions of plastics relative to wood can be harder to control than fires involving primarily wood, given similar warehouse fire prevention systems.

NFPA 13 Requirements for Plastic Pallets without Flame Retardants

NFPA 13 covers requirements for sprinkler system design (in relation to building design), storage organization and management, as well as assessment of the risks of warehouse contents, including pallets. The standard establishes requirements for the management of potential risks from non-flame retardant plastic pallets that are more stringent than those for wood pallets for two different situations in a warehouse:

⁶¹ The standard for flammability of wood pallets was established using red oak. As the table shows, however, the differences between woods are significantly less than the differences between any of the woods and either PE or PP. FAA, “Thermal Analysis of Polymer Flammability” (FAA Table 4), DOT/FAA/AR-07; Mark Diitenberger, “Ignitability of Materials in Transitional Heating Regimes,” U.S. Forest Service, TreeSearch, <http://www.treesearch.fs.fed.us/pubs/7018>; Richard N. Walters et al, “Heats of Combustion of High Temperature Polymers,” <http://www.fire.tc.faa.gov/pdf/chemlab/hoc.pdf>; *The Fire Safety Handbook*, US Department of Agriculture, Forest Service, Forest Products Laboratory.

⁶² MJ/kg refers to megajoules per kilogram.

⁶³ *The Fire Safety Handbook* published by the US Department of Agriculture, Forest Service, Forest Products Laboratory, references heat release factors for soft woods and hardwoods.

- Stored commodities on pallets.⁶⁴
- Empty ('idle') pallets.

Maine follows the NFPA 13 standards⁶⁵ at the state level, and most localities have also incorporated them by reference into their ordinances. For the most part, the local ordinances incorporate NFPA 13 without changes. A few localities have included additional requirements (e.g., specific requirements for areas of buildings requiring additional sprinkler protection), but none that bear on the use of plastic pallets. In addition, Maine has adopted the International Building Code (IBC), which becomes mandatory for all Maine communities in December 2010.⁶⁶

Non-Flame Retardant Plastic Pallets with Commodities

In determining the levels of fire protection required for products stored in warehouses, NFPA classifies commodities on the basis of the threat they pose once ignited. The categorization system includes four commodity classes (Class I through IV, with Class I representing the lowest risk) plus an additional categorization of plastics commodities (Group A through Group C). Cartoned, unexpanded Group A plastic products pose the highest fire risks and are covered in Class IV, while Group B & C plastic products are covered in Classes III & IV. (See Class summaries and examples in Table 2.3).

While commodity classes are only one of the factors affecting warehouse fire protection requirements, an increase in the classes of commodities typically stored in a warehouse may require an increase in the level of warehouse fire protection, possibly involving changes such as increased density of sprinklers, changes in sprinkler placement, larger orifice sprinklers and/or increased water supply or pressure, particularly for older warehouses. The higher protection levels may apply to an entire warehouse or only to particular areas of a warehouse segregated for storage of higher risk commodities (e.g., a section of a grocery warehouse with products such as cooking oils in plastic containers). If

⁶⁴ NFPA 13 defines a "commodity" as "the combination of products, packing material, and container that determines commodity classification." Section 3.9.1.6.

⁶⁵ Maine's Office of the State Fire Marshal currently uses the 2007 edition of NFPA 13.

⁶⁶ Maine Revised Statutes Annotated, Title 10, chapter 1103 (§§9721 -9725), as amended by Public Laws 2009, chapter 261. <http://www.mainelegislature.org/legis/statutes/10/title10ch1103sec0.html>.

Maine has not adopted the International Fire Code (IFC), another international code on fire protection standards. Personal communication from: Eric Ellis, Maine Office of State Fire Marshal; Chief Robert Lefebvre, Fire Chief, Gorham, Maine, October 19, 2010; Captain David Jackson, Scarborough Fire Department, Fire Prevention Bureau, email October 15, 2010; Captain Charles Jarrett, Fire Inspector, Westbrook Fire Rescue Department, email October 14, 2010.

higher risk commodities are not segregated, the commodity rating determining the protection levels required is determined by the highest risk commodities stored.⁶⁷

Table 2.3: Commodity Categories: Examples of Products/Materials from NFPA Automatic Sprinkler System Handbook⁶⁸	
Class I- Noncombustible product on wood pallet, in single-layer corrugated carton, or shrink- or paper-wrapped as unit load: <i>major appliances, canned foods, fresh fruit w/ non-plastic containers, meat products (bulk), milk, canned nuts.</i>	Class II- Noncombustible product in slatted wooden crate, solid wood box, multi-layered corrugated carton with or without pallet: <i>light fixtures in non-plastic cartons, pharmaceuticals in glass bottles or cartons, noncombustible liquids (e.g., ketchup) in plastic containers.</i>
Class III- Wood, paper, natural fiber or Group C plastic product with or without cartons, boxes, crates or pallets & up to 5% of Group A or B plastics: <i>aerosols, dried beans, packaged candy, cereal, clothing (natural fiber), wood products (furniture, toothpicks, doors), mattresses, paper products (books, newspapers, tissue products in cartons), diapers.</i>	Class IV- Products made from Group B plastics, free-flowing Group A plastic materials, ⁶⁹ containing 5-15% (by weight) or 5-25% (vol) Group A plastics (including packaging): <i>ammunition; empty PET jars; waxed paper in cartons; rayon & nylon fabrics; natural rubber blocks in cartons; vinyl floor tiles in cartons; wax-coated paper cups or plates; pharmaceuticals in plastic bottles in cartons.</i>
Group A Plastics (highest risk): <i>acrylic, PET, polycarbonate, polyethylene, polypropylene, polystyrene, including products such as candles, butane lighters, foam plastic cushioning, stuffed foam toys, combustible or noncombustible solids in plastic containers, synthetic rubber.</i>	Group B Plastics: <i>cellulosics, chloroprene rubber, nylon, silicone rubber, fluoroplastics (ECTFE, FEP), nylon 6, natural rubber (not expanded).</i>
	Group C Plastics: <i>PVC, PVDC, melamine formaldehyde, phenolics, fluoroplastics (PCTFE, PTFE), urea formaldehyde.</i>

⁶⁷ NFPA 13, section 5.6.1.2 on mixed commodities. The standard does allow for some extremely limited amounts of higher risk commodities to be dispersed among predominantly lower risk commodities in the warehouse.

⁶⁸ NFPA, *Automatic Sprinkler Systems Handbook*, 11th Edition (2010), edited by James D. Lake. This *Handbook* includes both the text of NFPA 13 and interpretations and commentary on NFPA 13 provisions. See Tables A.5.6.3.1-4, section 5.6.4.

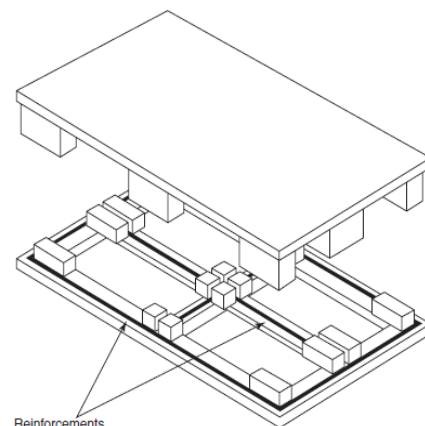
⁶⁹ NFPA 13 defines free-flowing plastic materials as, “those plastics that fall out of their containers during a fire, filling flue spaces, and create a smothering effect on the fire.” Section 3.9.1.15.

What is the impact of plastic pallets without flame retardants on these commodity levels? Polyethylene and polypropylene, common polymers for plastic pallets, are listed as Group A plastics, and would be anticipated to contribute to the severity of any fire that broke out in a warehouse. As a result, if commodities are stored on non-flame retardant plastic pallets, the risk level of the commodity increases. There are two possibilities, depending on the construction of the pallet.⁷⁰

- If the pallet on which the commodities are stored is made of unreinforced polypropylene (PP) or high density polyethylene plastic (HDPE), the classification of a Class I through Class IV commodity is increased one class. So a Class III commodity would become Class IV, and a Class IV commodity would become a cartoned, unexpanded⁷¹ Group A plastic commodity. Since there is no higher commodity risk level, there would be no increase for a Group A plastic commodity.
- Some pallets are reinforced with embedded steel rods to strengthen the plastic. If the pallet on which the commodities are stored is made of reinforced PP or HDPE, the classification of a Class I through Class III commodity is increased two classes. So a Class II commodity would become Class IV, and a Class III commodity would become a cartoned, unexpanded Group A plastic commodity. Once again, Group A is the highest risk classification, so a Class IV commodity would be classified as Group A.⁷²

Since reinforcing rods in a plastic pallet are not visible, unreinforced PP or HDPE plastic pallets must be marked with a symbol indicating that they are not reinforced. Any pallet without a permanent marking or manufacturer's certification that it is unreinforced will be

Exhibit 2.1: Cut-Away Image of Reinforced Plastic Pallet



Picture from NFPA, Handbook, p.62.

⁷⁰ NFPA 13, sections 5.6.2.2 and 5.6.2.3.

⁷¹ Expanded (foamed or cellular) plastics are those plastics whose density is reduced by the presence of numerous small cavities dispersed throughout their mass.

⁷² NFPA's higher commodity increase for reinforced plastic pallets is based on the results of Underwriters Laboratories (UL) fire tests of commodities on both reinforced and unreinforced PP and HDPE pallets. *Handbook*, p. 100. Possible explanations include that the failure of reinforced plastics to collapse leaves more surface area exposed to the fire and that the rods may conduct heat.

considered reinforced, and the commodity classification will be increased by two levels.⁷³

Empty Non-Flame Retardant Plastic Pallets: 'Idle Pallets'

Empty pallets, often in stacks, waiting for commodity loads or shipment to another location, are called “idle pallets.” Stacks of idle pallets pose a major fire challenge. According to the *Handbook* for NFPA 13:

Idle pallet storage introduces a severe fire condition. Stacking idle pallets in piles is the best arrangement of combustibles to promote rapid spread of fire, heat release, and complete combustion.... Idle pallets create an ideal configuration for efficient combustion by presenting many surfaces for burning and many openings that provide an almost unlimited source of air. At the same time, the configuration shields much of the burning surfaces from sprinkler discharge. In addition, pallets are subject to easy ignition due to their frayed, splintered edges and typical dried out condition.⁷⁴

Factory Mutual Insurance Company (FM) provides this assessment of the increased fire risk from idle pallets:

It should be noted that the relative hazard or classification of a commodity is a function of both the material and its configuration. For example, a solid block of wood is relatively difficult to ignite and slow to burn. If, however, the wood is in a configuration that maximizes surface area and has parallel surfaces to encourage re-radiation and convection (e.g., idle wood pallets), it burns much more rapidly. The large amounts of heat released under such circumstances can result in a hazard beyond that normally associated with the primary material of the product: idle wood pallets are much more hazardous than Class 3 commodities, although wood products are generally considered Class 3 commodities.⁷⁵

As with palletized products, NFPA 13 applies stricter requirements to storage of idle, non-flame retardant plastic pallets than to storage of idle wood pallets.

- Warehouses or manufacturing sites can store stacks of both kinds of idle pallets outdoors or in a detached building or structure, but the NFPA 13 *Handbook* recommendations suggest greater control may be necessary for stacks of idle plastic pallets.⁷⁶

⁷³ NFPA 13, section 5.6.2.3.1.

⁷⁴ *Handbook*, A12.12, 12.12.1, p. 546.

⁷⁵ Factory Mutual Global Property Loss Prevention Data Sheet 8-1, “Commodity Classification,” p. 3.

⁷⁶ NFPA 13, sections 12.12.1.1 & 12.12.2.1. The *Handbook* differentiates between wood and non-flame retardant plastic pallets even for outside storage, providing different recommended distances from the

- For indoor storage, there are significant differences. For idle wood pallets, the standard specifies:
 - A range of possible combinations of sprinkler types and orifice sizes for different idle wood pallet stack heights and storehouse ceiling heights, starting with smaller orifice, standard response sprinklers for smaller storage heights and continuing through options for large orifice Early Suppression Fast Response (ESFR) sprinklers for higher storage heights;; or
 - Under the lowest rated sprinklers, 4-stack piles of idle wood pallets up to 6 feet high, separated from other piles by at least eight feet or 25 feet of commodity.
- For idle plastic pallets, the standard's more stringent options require either that:
 - Indoor storage be in a cutoff room;
 - Storage of idle plastic pallets without cutoff rooms should be limited to 2-stack piles of no more than four feet; or
 - Sprinkler protection for higher storage heights should be provided only by larger orifice Early Suppression Fast Response (ESFR) sprinklers.⁷⁷

Potential for Management Practices to Provide Safer Alternative to Use of DecaBDE

For management of products on plastic pallets and idle plastic pallets, there are potential solutions for meeting the levels of fire protection mandated by NFPA 13 without requiring that the plastic pallets be made with flame retardants. The alternative lies in a combination of warehouse/sprinkler system design and best practices for management and organization of stored commodities and idle pallets.

For storage of products on plastic pallets, NFPA 13 specifies that if warehouses already meet sufficiently high standards for fire protection sprinkler systems, the one- or two-step increases in commodity classifications for products on plastic pallets no longer need to be considered.⁷⁸ Similarly, the allowable storage heights and warehouse ceiling

building depending on the numbers of pallets in the stacks for wood, while stating only that consideration should be given to the heat generation potential of the materials in plastic pallets [Handbook, A.12.12.1.1]. The FM Global Data Sheet on "Idle Pallet Storage" (8-24) spells this difference out in more detail, specifying greater distances from the building and between stacks of pallets for plastic than wood pallet stacks of similar heights. FM Global Loss Prevention Data Sheet 8-24, Table 2.

⁷⁷ NFPA 13, section 12.12; Table 12.12.2.1; personal communication from Carl Wiegand, Fire Protection Engineer, National Fire Sprinkler Association, October 5, 2010. ESFR sprinklers are designed to respond quickly to the fire with enough water to suppress it before it can grow and spread.

⁷⁸ NFPA 13, section 5.6.2.5. "For ceiling-only sprinkler protection, the requirements of 5.6.2.2 [for commodity classifications with unreinforced plastic pallets] and 5.6.2.3 [for commodity classifications with

heights for indoor storage on the floor or in racks without solid shelves are the same for idle plastic pallets and idle wood pallets when protected with identical larger orifice ESFR sprinkler systems – systems designed to suppress a fire as it starts through a combination of very quick response and large volumes of water.⁷⁹

Installing more effective fire protection sprinkler systems and following best management practices within a warehouse could provide a “safer alternative” for continued use of plastic pallets without using flame retardant plastic pallets with decaBDE. To what extent is this viable statewide solution for Maine or for warehouses nationally?

Some warehouses, particularly those built more recently, meet the required design criteria, either in particular areas of the warehouse or overall. But costs may be a limiting factor in installing the most advanced systems, particularly for older warehouses that would require retrofitting, but to some extent even for newer warehouses.

Sprinkler fire protection depends not only on the sprinklers’ speed of response to the fire, but on other factors such as the size of the sprinklers’ orifices, sprinkler density and orientation, and the availability of adequate water volume and water pressure. In addition to the higher costs for the larger orifice sprinklers, the added water demand for these systems may require installation of pumps to ensure adequate system pressure, or even installation of tanks to ensure the availability of a sufficient water supply.⁸⁰

While warehouses that have installed sprinkler systems with the largest orifice sprinklers are relatively rare, there are several such warehouses in Maine – primarily in warehouses that have high piles of storage or the highest-risk plastic commodities. Such sprinkler systems are most frequently found in newer warehouses, partly due to changes in fire suppression technology. The use of ESFR sprinkler systems with larger orifices didn’t emerge until the late 1980s and older warehouses are unlikely to have the most advanced systems. Even newer warehouses, or older warehouses that have

reinforced plastic pallets] shall not apply where plastic pallets are used and where the sprinkler system uses spray sprinklers with a minimum K-factor of K-16.8.”

⁷⁹ NFPA 13, Tables 12.12.1.2(c) and 12.12.2.1.

⁸⁰ For example, cheaper sprinklers can be in the range of \$30-40 per sprinkler; while the largest orifice sprinklers for an ESFR system can cost several hundred dollars per sprinkler; personal communication from Carl Wiegand, National Fire Sprinkler Association; Ken Linder, Swiss RE, chair of NFPA Design Discharge Committee, 10-22-10; Eric Ellis, Fire Protection Engineer, Maine Office of State Fire Marshal, 10-1-10.

upgraded, may have compliant systems that aren't sufficient to meet the protection requirements for plastic pallets without flame retardants.⁸¹

In terms of providing an adequate alternative for fire protection against the risks from plastic pallets without flame retardants, the limitation is that a significant proportion of warehouses lack the required sprinkler protection systems throughout the entire warehouse and are unlikely to upgrade in the near future. These warehouses can take other steps (e.g., increased aisle width; outside storage of idle pallets) to reduce the fire hazard associated with the use of plastic pallets, but adherence to such practices alone is insufficient to offset the sprinkler system limitations for the purposes of compliance with NFPA 13. A number of warehouses have separate areas with adequate protection for the highest risk Group A plastics. They also may use non-flame retardant plastic pallets that can be segregated and stacked separately when idle for use in deliveries from the warehouse to their own stores. But for most of their storage area, any plastic pallets would need to be flame retardant.

For example, the Hannaford warehouse in South Portland has higher protection areas for products such as cooking oils in plastic containers. It uses nestable plastic pallets without flame retardants to send to Hannaford stores, and stores them in small stacks meeting NFPA requirements when returned from the stores. But inbound products from suppliers on plastic pallets that will be stored on racks before being re-palletized for delivery to stores must be on fire-retardant plastic pallets.⁸²

There is a large market for non-flame retardant plastic pallets. A spokesman for Orbis estimated that only about 5% of the plastic pallets customers buy are flame retardant.⁸³ This market includes captive systems where the pallets will only be used internally in a fully-protected warehouse or manufacturing site, or only travel between sites, fully under the control of the company, that meet NFPA standards for high risk commodities.

But the open-pooled pallet market faces different conditions. Shipments on pooled pallets will be sent to many warehouses that, even though compliant with fire protection standards, are not adequate for protecting against the risks from plastic pallets without flame retardants. So advanced fire protection sprinkler systems and best management practices are a solution to part of the problem of finding a safer alternative for decaBDE, but not an answer for all situations.

⁸¹ Personal communication from Eric Ellis, Maine Office of State Fire Marshal; Carl Wiegand, National Fire Sprinkler Association.

⁸² Personal communication from Al Hussey, Warehouse Manager, Hannaford Warehouse, South Portland, Maine, September 13, 2010.

⁸³ Personal communication from Curt Most, Sales Manager, Plastic Pallets, Orbis Corporation, September 21, 2010.

Plastic Pallets with Flame Retardants

The other alternative provided by NFPA 13 for managing the fire risks from plastic pallets is that they be made with flame retardants and pass approved tests to demonstrate that their fire risk is equivalent to or less than that posed by wood. With respect to increased commodity classifications, section 5.6.2.6 states:

The requirements of 5.6.2.2 [for unreinforced plastic pallets] and 5.6.2.3 [for reinforced plastic pallets] shall not apply to non-wood pallets that have demonstrated a fire hazard that is equal to or less than wood pallets and are listed as such.

For storage of idle plastic pallets, NFPA section 12.12.2.1(6) states:

Indoor storage of non-wood pallets having a demonstrated fire hazard that is equal to or less than idle wood pallets and is listed for such equivalency shall be permitted to be protected in accordance with 12.12.1 [protection standards for wood pallets].

Two organizations provide testing to determine whether a plastic pallet may be considered equivalent to wood under NFPA 13. These are the Underwriters Laboratory (UL), a non-profit consensus-based standards organization, and Factory Mutual (FM), an ANSI-accredited standards developing organization active in both fire protection insurance and testing. The relevant testing standards are:

- UL 2335, Standards for Fire Tests of Storage Pallets.
- ANSI/FM 4996, American National Standard for Classification of Idle Plastic Pallets as Equivalent to Wood Pallets.

A company with a flame-retardant plastic pallet must put its pallet through large-scale fire tests to determine whether it performs as well as a wood pallet with respect to specific predetermined parameters. These tests are complex and costly, and designed to determine not only material attributes, but the effect of fire dynamics on large numbers of such pallets in a setting that replicates some of the factors that could determine fire risks in an actual warehouse setting.

Exhibit 2.2: Idle Pallet Fire Test⁸⁴



The tests have both similarities and differences:⁸⁵

- UL 2335 requires both idle pallet and commodity storage tests. The idle pallet test provides two alternative arrangements of 12 foot high stacks (6 or 14 stacks) of pallets that are tested for response with uniform firing and sprinkling. The commodity storage test (actually a sequence of three tests) involves testing a specified Class II commodity on eight pallets on 2-level racks (a 2x2x2 arrangement). The test is conducted three times with different water discharge levels (from .11 to .31 gallons per minute per square foot). Test results are measured against specific required acceptance criteria.
- FM 4996 tests 16 stacks of idle pallets arranged on 2-level racks (a 2x4x2 arrangement); the inside four stacks on each level are the pallets being tested (2x2x2), while outside stacks on each row and level are wood pallets. The pallets being tested have to perform as well as, or better than, the measured criteria for wood pallets, and may not exhibit “excessive melting, dripping or pooling.” In addition, specimen sheets of the pallet materials are subjected to additional fire tests, both without and with “accelerated weathering” testing (a six week

⁸⁴ “Material Handling Pallets: Regulatory Landscape,” Presentation by Bruce Torrey, iGPS at the University of Massachusetts at Lowell, June 17, 2010.

⁸⁵ For more detailed information on the design of the tests, arrangements and numbers of pallets, etc., see the standards.

process of exposure to UV light and condensation), to determine if such weathering results in adverse effects on the fire mitigation attributes of the material. FM 4996 does not include a test of plastic pallets with commodities.

For many, these two tests appear to be accepted as roughly equivalent. The handbook published by NFPA to provide explanation and commentary on NFPA 13 states (though it is important to note that, as stated in a notice at the beginning of the handbook, “the commentary and supplementary materials in this handbook are not a part of the NFPA Document and do not constitute Formal Interpretations of the NFPA....”):

“Plastic pallets present a unique challenge for sprinkler protection. Recent studies and product development, along with significant fire testing, have shown that some plastic pallets have been tested and have demonstrated a fire hazard that is equivalent to or less than the fire hazard presented by wood pallets. Plastic pallets meeting these requirements are specifically listed as such. The requirements for adjustments in the commodity classification due to the use of different types of plastic pallets are based on UL 2335, *Standard for Fire Tests of Storage Pallets*, and ANSI/FM 4996, *American National Standard for Classification of Idle Plastic Pallets as Equivalent to Wood Pallets*, large-scale calorimeter tests. Listed plastic pallets are available that exhibit fire performance similar to that of wood pallets in these tests and can be treated as equivalent to wood pallets for commodity classification”⁸⁶

A spokesman for the Maine Office of State Fire Marshal stated that approval under either standard would be sufficient to meet the NFPA 13 requirement for demonstrating a fire hazard that is equivalent to wood.⁸⁷

But the adequacy of the FM 4996 test for meeting these criteria is disputed. A fire protection consultant emphasized that the Handbook, although published by NFPA, is not definitive, and commented that the lack of a commodity test as part of the FM 4996 testing regimen is a weakness. He felt that Factory Mutual’s requirement for greater sprinkler density in warehouses they insure makes FM 4996 sufficiently protective for those warehouses, but that plastic pallets meeting only the FM4996 standard managed the same way as wood pallets in warehouses not insured by FM would leave those warehouses vulnerable to greater fire risk.⁸⁸

The lack of a definitive consensus on this issue was summarized by the chair of one of the relevant NFPA committees: “A product that is UL listed or FM approved would meet

⁸⁶ *Handbook*, p. 100.

⁸⁷ Personal communication from Eric Ellis, Maine Office of State Fire Marshal, October 1, 2010.

⁸⁸ Personal communication, Jesse Beitel, Hughes Associates, Inc., December 2, 2010.

the definition of Listed per in section 3.2.3 of the standard.” But he added: “Note that the definition includes the phrase ‘list published by an organization that is acceptable to the authority having jurisdiction....’ As a result some AHJs [Authorities Having Jurisdiction] may accept both and some may not.”⁸⁹

Manufacture of Plastic Pallets and Approvals under UL 2335 and FM 4996

As evident from Table 1.5 (Chapter I), only a small number of manufacturers, even among those who manufacture plastic pallets, are engaged in producing flame retardant plastic pallets, or in exploring opportunities for using flame retardants other than decaBDE with plastic pallets. As the above summary makes clear, developing and marketing a flame retardant plastic pallet requires, in addition to substantial R&D and bench testing, a significant investment in an extensive testing and evaluation process. The total cost for the full-scale testing required to achieve either the UL 2335 Classification ‘listing’ or the FM 4996 Approval ‘listing’ runs approximately \$100,000. Even an idle pallet test for R&D purposes might cost \$10,000.⁹⁰

While a great deal of the relevant information is proprietary, Table 2.4 below provides a summary of publicly available information on current approvals and pending tests under both UL 2335 and FM 4996. One unusual entry in the table is that involving the listing of the CHEP wood pallet under FM 4996. Some of the CHEP pallets (less than 20%), while primarily made from wood, use a wood composite with a plastic resin for the pallet’s nine blocks. Under NFPA 13, the presence of the plastic resin requires that the pallet be listed as an approved pallet.⁹¹

From a fire prevention perspective, it is clear that decaBDE has been effective in enabling plastic pallets to meet the NFPA 13 flame retardant standards. But with the combination of state phaseouts and US EPA’s voluntary agreement with industry to end all sales of decaBDE in the US by the end of 2013, several pallet manufacturers are in the process of assessing and developing alternatives. The following Chapters will review what has led the pallet manufacturers to consider decaBDE an effective choice, and the efforts to develop safer alternatives that can be used to produce pallets that meet both performance and fire protection requirements.

⁸⁹ Personal communication, Kenneth Linder, Swiss Re; chair of the NFPA Design Discharge Committee, email, November 29, 2010.

⁹⁰ These estimates were provided by Bruce Torrey, Vice President, Technology at iGPS, email to Ken Soltys, Pure Strategies on November 22, 2010.

⁹¹ The NFPA 13 requirement is based on its definition of a “plastic pallet” in section 3.9.1.21 of the standard: “A pallet having any portion of its construction consisting of a plastic material.” Personal communication from David Deal, Director Product Services and Industry Affairs, December 6, 2010.

Table 2.4: Manufacturers of Flame Retardant Plastic Pallets ⁹²

Manufacturer	Pallet Type	Polymer Type	Flame Retardant in Currently Listed Pallet	FM	UL	Status of Development of Pallet with Alternative Flame Retardant
ORBIS	Rackable/ Stackable Nestable	PE	DecaBDE & Sb ₂ O ₃ ⁹³	Yes	No	waiting for large fire test
Plastics Research	Rackable	No Info	No Information	Yes	No	
Polymer Pallets	No Data	PVC		No	Yes	
Polymer Solutions International	Rackable/ Stackable Nestable	HDPE	DecaBDE/Sb ₂ O ₃	Yes	No	
Rehrig Pacific Company	Rackable, Nestable	PP	Magnesium Hydroxide	Yes	Yes	
Schoeller Arca Systems	Rackable/ Stackable	HDPE	DecaBDE/ Sb ₂ O ₃	Yes	Yes	Under development
TMF Corporation	Rackable	PE	DecaBDE/ Sb ₂ O ₃	Yes	No	waiting for large fire test
CHEP	Rackable/ Stackable	PP & HDPE	Proprietary phosphorus-based	Yes	Yes	
CHEP Wood Pallet with wood/plastic composite blocks	Rackable/ Stackable	Wood	It doesn't need a flame retardant to pass the tests	Yes	No	

⁹² Data gathered from personal communications with Bruce Torrey of iGPS on 8/17/2010; Curt Most of ORBIS on 9/21/2010; Amy Lander of Rehrig Pacific on 9/7/2010; Debbie Bergen of TMF on 9/7/2010. While the new Orbis pallet uses some form of non-halogenated flame retardant, it is not certain whether the new TMF pallet uses a non-halogenated flame retardant or an alternative (non-decaBDE) brominated flame retardant.

⁹³ Decabromodiphenyl ether (decaBDE) is almost always used in combination with antimony trioxide (Sb₂O₃).

Chapter III: Balancing Pallet Performance & Flame Retardant Goals

In developing, over the last decade, plastic pallets that could be used interchangeably with wood pallets in any warehouse setting, designers and manufacturers have focused on balancing physical performance characteristics and flame retardance. As evidence of the environmental and human health risks of the flame retardant in the favored combination of HDPE and decaBDE has accumulated, the need for ensuring reduced toxicity of the components of plastic pallets has become an additional factor in the required balance. Chapter VI addresses the toxicity issues related to potential fire retardant additives. Chapters III-V discuss the challenges involved in addressing the other parts of the balance – combining flame retardant and pallet performance goals.

Reducing Fire Risks of Plastic Pallets⁹⁴

What are the major flame retardant technologies and how do they work?

Reasons Why Pallet Manufacturers Selected the Flame Retardant DecaBDE

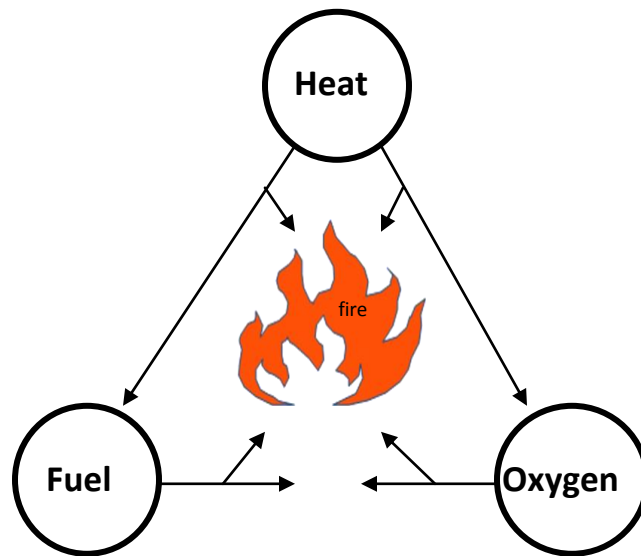
“It performed significantly better than any other flame retardant on the market at that time, including other brominated products. It was the only product that needed less than 10% of the additives to get the results needed, which included weight, modulus retention, impact retention, processing (injection, extrusion, forming, welding). Another factor was availability (industry capacity) as well as cost.”

Bruce Torrey, iGPS

There are three elements required for a fire. They are fuel, oxygen, and energy or heat. These three elements comprise the classic “fire triangle” (see Figure 3.1). This simplified representation of the combustion process has been used throughout the flame retardant industry literature for many years.

⁹⁴ Both this section and the following section (“Pallet Performance Characteristics”) of this chapter prepared for this report by James Innes & Ann Innes of Flame Retardants Associates.

Figure 3.1: The Classic “Fire Triangle”



It may help to envision a burning candle. When one asks why the candle continues to burn once lit, the answer can be found in the fire triangle. Wax, the material of which the candle is made, is the fuel. The wax, which is melted by the flame heat, migrates up the wick and is burned or pyrolyzed (chemically changed) at high temperatures. The gases which result continue to undergo chemical reactions in the flame, components of which eventually interact at even higher temperatures with oxygen at the outer edge of the flame. As long as the fuel (candle wax) remains and the air (oxygen) is present at the candle flame, burning will continue.

So the three elements of the triangle are actually the critical determining parameters for fire. Fuel is contributed to any fire by the article or articles being burned. Important factors for fuel in the real world include aspects such as the types of furniture and their position in the room, other furniture characteristics such as size, shape, density, surface properties and other physical or chemical properties. The latter include heat of combustion, thermal conductivity, and ignition temperatures.

Oxygen is a required element for combustion. If one pinches the burning candle wick with fingers or uses a candle snuffer, the oxygen is removed from the candle burning scenario and the flame goes out. Energy or heat is generated during the chemical reactions occurring in the flame and at the flame-oxygen interface and, by interaction with the fuel, continues the burning process. Important factors include the proximity to the fuel and the chemical components generated from the combustion and

decomposition of the fuel.⁹⁵ Combustion or burning continues as long as the three triangle elements are present in sufficient quantity. If any one of these elements is removed or interfered with, the combustion process is disrupted. This removal or interference is the practical objective of flame retardants. Over several decades, researchers in the flame retardant industry have developed a large portfolio of flame retardant products which attack one or more of the three triangle elements.

The Three Major Flame Retardant Technologies

There are many flame retardant products under development and in commercial use today. Most of the older commercial flame retardant products can be classified into three major flame retardant technologies. The first of these technologies is also the oldest and could be described as the “workhorse” flame retardant technology. Halogenated flame retardant technology includes a large number of products which typically contain bromine, chlorine, or sometimes both. Specific product examples include Decabromodiphenyl oxide (decaBDE), Tetrabromobisphenol A (TBBA), and Hexabromocyclododecane (HBCD).

The action of halogen flame retardants during combustion is complicated. They are known to act mostly in the gaseous or vapor phase. During the combustion process, a persistent supply of chemical free radicals (elements such as hydrogen and/or carbon-hydrogen with free electrons)⁹⁶ is generated. The flame retardant decomposes during the combustion process to generate halogen acid gas. It is this gas which interacts with the chemical radicals, essentially “trapping” them, and thereby interrupting the combustion process. This mechanism is sometimes referred to as radical trapping and corresponds to the disruption of energy (or heat) on the fire triangle. This is a simple explanation of a complex reaction.⁹⁷

Halogen flame retardant products are almost always used in conjunction with other products called synergists. A synergist is defined as a product which, when used in combination with a flame retardant product, boosts the flame retardant performance to a level that is greater than that achieved if the respective flame retardant performance of the two products were simply added together. Synergists are used in specific ratios with the flame retardant product to maximize the flame retardant performance. The most well-known and widely used halogen flame retardant synergist is antimony

⁹⁵ “International Plastics Flammability Handbook”, Jürgen Troitzsch, Carl Hanser Verlag, Kolbergerstr, 22, D-8000 München, Germany, 1983, p. 12-15.

⁹⁶ “Van Nostrand Reinhold Encyclopedia of Chemistry”, Fourth Edition, Van Nostrand Reinhold Company Inc., 135 West 50th Street, New York, NY 10020, 1984, p. 406.

⁹⁷ Additional details including alternative explanations are available in the literature. See Troitzsch, 1983, Op.cit. p.47.

trioxide. This synergist is thought to boost effectiveness of the flame retardant system by ultimately generating antimony trihalide, which also acts as a radical trap. Again, this is a simple explanation of what actually is a much more complex series of actions, all of which interfere with the combustion process.⁹⁸ Halogen flame retardant products are used in a wide variety of resins including polyolefins, polystyrenes, polyamides (nylons), polyesters and more.

The second major flame retardant technology is also currently the fastest growing segment and is comprised of products called metal hydrates. The most well-known flame retardant metal hydrate is aluminum trihydrate (ATH). Another metal hydrate flame retardant that is growing in use is magnesium hydroxide or $Mg(OH)_2$. The interest in the magnesium hydroxide flame retardant product can be attributed at least in part to the current industry focus on environmentally friendly flame retardants. These metal hydrate flame retardants function by releasing water vapor in product specific temperature ranges. That reaction leads to several effects which interfere with the combustion process. The release of water vapor acts to cool the substrate by absorbing heat. In addition, an insulating metal oxide layer is formed on the substrate, and a dilutive effect is also produced in the flame front. Metal hydrate flame retardants interfere with at least two of the three triangle components - heat and fuel.⁹⁹ Metal hydrate flame retardants are also used in a variety of resins including polyolefins, olefinic elastomers, EVA (ethylene-vinyl acetate), PVC and some epoxies.

The third major flame retardant technology includes products containing phosphorus. Common FR products include ammonium polyphosphate (APP), red phosphorus, and other phosphates and phosphonates. Well-known and well-used products of the phosphate ester type include resorcinol diphosphate (RDP), and bisphenol A diphosphate (BDP). The flame retardant mechanism for phosphorus-based products is largely perceived to be a char-forming mechanism following the decomposition to phosphoric or polyphosphoric acids during the combustion process. However, depending on the specific phosphorus flame retardant product and the resin substrate type, the actual flame retardant mechanism can be multifunctional and may also include vapor phase activity (like that of the halogen flame retardants) and/or cross-linking mechanisms.¹⁰⁰

⁹⁸ Troitzsch, 1983, Op.cit., pp. 48-49.

⁹⁹ Again the interested reader is referred to the literature for further details. See "Compounding metal hydrate flame retardants", Jim and Ann Innes, *Plastics Additives & Compounding*, Vol. 4, Issue 4, Elsevier Advanced Technology, PO Box 150, Kidlington, Oxford, OX5 1AS, UK, April 2002, p.23.

¹⁰⁰ Consult FR industry references for further details. See: "Plastics Flammability Handbook", 3rd edition, Jürgen Troitzsch, Carl Hanser Verlag, Munich Germany, 2004, pp.133-153, p. 533.

Phosphorus containing flame retardant products are used in resins including PVC, acrylonitrile butadiene styrene (ABS), PC/ABS, polyamides and polyphenylene oxide (PPO). The amount of phosphorus compound (with synergists and/or other additives) that must be loaded into the polymer to achieve flammability performance depends on the polymer type.

Although the above are considered the three major flame retardant technologies, there are of course a number of flame retardant products which do not fit into those groups. These include products based on nitrogen, sulfur, boron, graphite, and silicone.

Smoke suppressants are a separate class of product often discussed with flame retardants. Smoke is composed of water, carbon particles, ash, soot and other combustion by-products which are contained in combustion of gas and air. This collection of components is perceived by the human eye as smoke. Smoke suppressants are compounds which work to suppress the production of smoke during the combustion process. Metal hydrate and char-forming flame retardant products can be considered smoke suppressants in and of themselves. The metal hydrate products, by their nature and mode of action, produce lower smoke and the char formers effectively retain carbonaceous material in the solid phase (preventing the subsequent contribution to smoke production). There is another type of smoke suppressant which essentially works in flame retardant systems containing halogen flame retardant compounds. These include products based on molybdenum and zinc compounds. Molybdenum oxide and ammonium octamolybdate (AOM) are among the older, more widely recognized products. Such products work in the solid phase through cross-linking and other modifications to the pyrolysis process. All of these work to keep the fuel in the solid phase.¹⁰¹

Finally, mention should be made of nanotechnology, the leading focus in flame retardant technology development today. Nanotechnology is seen in a variety of industries and applications, not just in flame retardants. Nano is usually defined as one-billionth (or 10^{-9}). In flame retardant technology, nano does not mean one billionth. Nano composite polymers are polymers with a different internal structure such as alternating nanometer-thick layers of organic and inorganic materials. These frequently impart flame retardancy to the systems in which they are incorporated. This technology is relatively new and will not be applicable to the subject of flame retardant plastic pallets. However, the exciting aspect of this nanotechnology in flame retardant

¹⁰¹ "Flame Retardants in Commercial Use or Development for Polyolefins", Edward Weil, Sergei Levchik, Journal of Fire Sciences, Vo. 26, No. 1, 5-43, January 2008, Sage Publications Ltd., 1 Olivers Yard, 55 City Road, London EC1Y 1SP, UK, Sage Journals Online, <http://jfs.sagepub.com>.

technology is the improvement in physical and mechanical properties often found in addition to possible improvement in flammability. These improvements are highly valued as the use of flame retardant additives in thermoplastic formulations frequently adversely affects physical and mechanical properties of the formulation. Indeed one of the tricks in successfully using flame retardant additives is how to balance the opposing effects of increased flammability performance and decreased physical/mechanical properties.

Pallet Performance Characteristics¹⁰²

Pallets must be strong enough to support the loads being placed on them, hold the loads in a stable fashion during transport, fit through doors of varying sizes, be durable and impact-resistant, be reusable in a significant way, stack easily, and pack tightly inside intermodal containers or trucks/vans to maximize the shipping space inside the container. To summarize: five interactive design parameters are usually of importance in designing a pallet: strength, stiffness, durability, functionality and cost. These are interactive and the trick is balancing these properties. Maximizing just one will have an impact on the others.

The key to a successful flame retardant plastic pallet is to design a pallet meeting all the necessary physical properties and the required flammability performance by using the proper choice of polymer resin, flame retardant system, and other additives (colorants, impact modifiers, etc.). All of these pallet requirements must be met with a formulation that is not cost-prohibitive. Flame retardancy standards and testing have already been reviewed. Cost will be discussed in the next chapter. Immediately below, the remaining four properties will be briefly discussed.

Strength generally refers to the amount of weight a pallet can carry both at rest and in motion during shipping and in storage environments. Pallets can be strength-tested using standardized pallet testing methods. One such method is ASTM D1185-98a (2009), Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping. There are several test protocols in this standard including conditioning requirements, static stiffness and strength tests, and dynamic tests of structural reliability. See Table 3.1 for a summary of some of the applicable test criteria for the static tests, as well as for some of the dynamic tests. For the best understanding

¹⁰² This section of the chapter, as the preceding section, prepared for this report by James Innes & Ann Innes of Flame Retardants Associates.

of these test protocols, the reader is referred directly to the standard in its entirety¹⁰³. Additionally, there is a design program (PDS –Pallet Design System) developed by Virginia Tech Pallet Laboratory. This is thought by many to be the best predictor of strength for wood pallets¹⁰⁴.

Table3.1: Key Pallet Performance Properties¹⁰⁵

ASTM 1185 “Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping”

Static Test	Test Load Level	Maximum Allowable Deformation After 2 hours under test load	Maximum Residual Deformation after 1 hour	Test	Significance to User
Compression tests of deck spacers	1.1xMR	0.160 inches (4 mm)	.06 inches (1.6 mm)	ASTM 1185 Test 8.3	Measures the total load a pallet can support without bulging or deforming -“Stack Load Capacity”
Bending tests on pallets	1.25xMR	0.019xL ₁ or L ₂ ¹⁰⁶	0.0075xL ₁ or L ₂ ¹⁰⁶	ASTM 1185 Test 8.4	A measure of the total load a pallet can support when suspended between two beams of a rack. – “Rack Load Capacity”
Bending tests on pallet decks on 48” span Top Bottom	1.1xMR ¹⁰⁷ 1.1x(M-1)R	0.015xL ₃ ¹⁰⁸	0.0053xL ₃ ¹⁰⁸	ASTM 1185 Test 8.5	Measures the total loads that the pallet deck can support when the top or bottom decks are suspended by slings or a forklift.

¹⁰³ ASTM D1185-98a(2009) “Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping, <http://www.astm.org/Standards/D1185.htm>

¹⁰⁴ Clarke, John. “Balance Your Pallet Design” in *Your Machinery Source*, Feb. 2002, Pallet User Education Series: Pallets & Packaging 101, <http://www.palletenterprise.com/educate.asp>.

¹⁰⁶ When supporting pallets under the top deck, the span between supports representing the largest deformation shall be used. “Standard Test methods for Pallets and Related Structures Employed in Materials Handling and Shipping,” ASTM D1185 – 98 (reapproved 2009), p.11.

¹⁰⁷ M is maximum number of unit loads stacked one on top of another during pallet use and R is a preliminary safe working load which is the average failure load adjusted to an appropriate safety level. (For wood pallets, this adjustment factor is often 0.35).

¹⁰⁸ L₃ is the longest space between deck spacers.

Dynamic Tests	Test Results	Test	Significance
Free fall drop tests	The pallet has failed the test if the observed damage in any pallet tested affects pallet rigidity, strength, or functionality.	ASTM 1185.9.3 Fall Drop Test from 40"	Measures the resistance to breakage when dropped from prescribed heights
Incline impact tests	The pallet has failed the test if the observed damage in any pallet tested affects pallet rigidity, strength, or functionality.	ASTM 1185.9.4 Incline Impact Tests on Pallet Deck Edges, Blocks or Posts, and Stringers—	Measures the resistance to breakage when a pallet is struck at angle by a fork lift
Vibration tests	The pallet has failed the test if the observed damage in any pallet tested affects pallet rigidity, strength, or functionality.	ASTM 1185.9.5 Vibration Tests on Loaded Pallet and load free pallet	Measures the resistance to breakage when subjected to vibrations on a vibration table

Stiffness is the ability of the pallet to resist deformation under load. With plastic, this can be a critical property to check, as plastic is renowned for having a “creep” factor; it moves or flows over time. Adequate pallet deck thickness can control this property and obtain the desired stiffness. Testing must be done to confirm adequate stiffness for the pallet’s intended use.

Durability refers to a pallet’s ability to retain integrity and remain whole and functional throughout its use life. The intended life can vary depending on the pallet’s purpose. Some need more durability while others need far less. Standardized test methods are available to assess this property.

Functionality: A pallet must be able to protect its load throughout the material handling process. Specific factors that are important in assessing the property of functionality include: opening heights between the top and bottom decks of the pallet; pallet weight; and deck friction. Standardized tests are available to help assess this property and include Material Handling Industry of America standard MH1-2005, Pallets, Slip Sheets, and Other Bases for Unit Loads¹⁰⁹.

¹⁰⁹ MH1-2005, “Standard on Pallets, Slip Sheets, and Other Bases for Unit-Loads”, Material Handling Industry of America, www.mhia.org.

Impacts of Flame Retardants on Pallet Performance

When flame retardants are added to the polymer used for making a plastic pallet, they don't just reduce the pallet's flammability. They can affect the strength, stiffness, durability and functionality of the pallet as well. Using information on non-halogenated flame retardants recommended for use in plastic pallets by a variety of sources, this section provides some examples of the challenges in simultaneously meeting flame retardant and performance goals.

All but two of the plastic pallets currently on the market in the U.S. are made with polyethylene, polypropylene, or high density polyethylene (polyolefins).¹¹⁰ Since that polyolefin polymer represents the bulk of the plastic compound used to make pallets, it is the main contributor to the flammability of the plastic. It is this flammability that the flame retardant must suppress in order to render a pallet equivalent to wood. Therefore, the search for alternatives has focused on flame retardants that have a history of being used in plastic products based on polyolefins.

The flame retardants in Table 3.2 were selected for consideration in this alternatives assessment on the basis of being recommended for, or used in making, a range of flame retardant plastic products. Some are already in use in plastic pallets. Examples of the use of non-halogenated flame retardants in plastics for other applications include:

- Clothing such as children's nightwear, hospital linen and technical fire-resistant textiles for fire fighters and military personnel;
- Electrical and electronic equipment such as TV and computer housings, household appliances, industrial electrical installations, and portable electronics;
- Transportation vehicles (airplanes, ships, trains, cars); and
- Wire and cable.

Table 3.2 contains the chemical name of the flame retardant, its Chemical Abstracts Number (CAS #), the manufacturer and product names, and the polymers used with these flame retardants. The column for "% Estimated for FM/UL Compliance " contains estimated concentrations of the flame retardant required to produce a plastic compound that could potentially be molded into a UL 2335-certified or FM 4996-approved plastic pallet. The last column contains references and some comments by the authors of those assessments.

Note that some of the flame retardants identified in this table are not used as the sole flame retardant additive. Almost all flame retardants are used in combination with

¹¹⁰ See Table 1.5, Chapter 1.

synergists or co-flame retardants that supplement the action of the prime flame retardant with complementary mechanisms. For example, US Patent 7,252,041 “Flame retardant polyolefin pallets and flame retardant master batch for their production” describes a combination of magnesium hydroxide, aluminum trihydrate and zinc borate used with polypropylene to make a flame retardant plastic pallet. DecaBDE is almost always used with antimony trioxide as a synergist. Whenever the information is available, candidate flame retardants should be evaluated with the recommended synergist and/or supplemental retardants. Keep in mind that these synergists and supplemental flame retardants also have an effect on the physical properties of the plastic compound.

Table 3.2: Estimated % Requirements of Non-Halogenated Flame Retardants for Plastic Pallets

Flame Retardant Chemicals	CAS #	Manufacturer/ Product Name	Polymer Applications	% Estimated For UL/FM Compliance	Source of Estimates ¹¹¹
Inorganic Metal Compounds					
Magnesium Hydroxide Particles treated with stearic acid or vinyl triethoxy silane to yield magnesium stearate and magnesium vinyl silane	01309-42-8	Martin Marietta Magnesium Specialties/ Mag Shield S	Polypropylene	23%	
ATH - Aluminum tri-hydroxide Particles treated with stearic acid or vinyl triethoxy silane to yield magnesium stearate and magnesium vinyl silane	21645-51-2	Alcoa Aluminum Aluminum Trihydrate	Polyethylene	>25%	
Zinc Borate Primarily used in conjunction with other flame retardants	138265-88-0	US Borax Firebrake ZB	Polypropylene	Used w/Magnesium hydroxide & ATH	
ATH/Mag Hydroxide/Zinc Borate	Mixture	Proprietary masterbatch	Polypropylene	12-25% Mag Hydrox 2-5% ATH 2-5% Zinc Borate	United States Patent: 7252041 Flame retardant polyolefin pallets and flame retardant master batch for their production

¹¹¹ Source of information on concentrations of flame retardants, unless otherwise identified, James and Ann Innes of Flame Retardant Associates.

Flame Retardant Chemicals	CAS #	Manufacturer/ Product Name	Polymer Applications	% Estimated For UL/FM Compliance	Source of Estimates ¹¹¹
Phosphates					
APP Ammonium Polyphosphate	6833-79-9	Clariant USA Exolit AP 422	Polyethylene, Polypropylene & HDPE	>12 %	
APP Ammonium Polyphosphate (ammonium polyphosphate + 6-10 % melamine synergists)	Mixture	Clariant USA Exolit AP 760	Polyethylene, Polypropylene & HDPE	10 - 30%	Exolit AP 760 MSDS
RP Red phosphorus (concentrates)	7723-14-0	Red Phosphorus NF Clariant	Polyethylene, Polypropylene & HDPE	>9%	Yields UL 94 V-2 NIST Fifteenth Meeting of the UJNR Panel on Fire Research and Safety
Trialkylated phenyl phosphate	Mixture	Phosphlex 71B	Modified polyphenylene oxides	Not available	Primarily used with NORYL® polymers
Bisphenol A Diphosphate	5945-33-5	Phosphlex	Modified polyphenylene oxides		Primarily used with NORYL® polymers
Amine phosphate salts					
Amino phosphate + amines + phosphates	Proprietary	JJAZZ	Polyethylene Polypropylene	30%- 40%	Combination of amine and phosphate gives added flame retardance JJAZZ MSDS. "Innovative and Novel Non-Halogen Flame Retardants" Nicholas A. Zaksek, Manager of Applications Research and Development, JJI Technologies (See Appendix VII).
Melamine cyanurate	37640-57-6	Ciba Metapur MC 350	Polypropylene	No recommendation available	On PINFA list but no history of being considered for pallets. PINFA - Nitrogen based flame retardants
Ethylene diamine phosphate (contains other proprietary amines)	14852-17-6		Polyolefins	No recommendation available	
Melamine polyphosphate	218768-84-4	Clariant Exolit AP 765	Polypropylene	>20%	Recommended by Clariant for injection molding grade polyolefins. Clariant Pigments & Additives - Exolit AP

The estimated levels of the flame retardants required to reduce the flammability of the plastic resins demonstrate a significant challenge in developing a range of effective replacements for decaBDE. The concentration of decaBDE in plastic pallets that are certified by UL 2335 and approved by FM 4996 is 5-10% plus 1-3% antimony oxide. But the estimated concentrations to achieve the same level of flame retardancy with the non-halogenated flame retardants in Table 3.2 (except for red phosphorus and possibly APP with synergists) are between 20 – 30%.

The incorporation of flame retardants, including decaBDE, into a plastic compound adversely affects the physical properties of the plastic, and consequently adversely affects the performance properties of a plastic pallet. Since all but two of the candidate alternatives must be used at higher concentrations than decaBDE, some of the candidate flame retardants would be expected to have a greater effect on the physical properties of the plastic than decaBDE. To illustrate how a flame retardant affects the properties of a polyolefin, Table 3.3 shows how increasing concentrations of magnesium hydroxide affect HDPE's melt flow index and tensile strength – key factors in the processability of the polymer and the weight-bearing strength of a pallet. These data indicate that the melt flow index is adversely impacted by increasing concentrations of magnesium hydroxide. As melt flow becomes too low, it reduces processability of the polymer during manufacturing, and this will result in a slower rate of pallet production. The tensile strength, however, although affected, is not reduced to an extent that would be considered a problem.

Table 3.3: Effect of Magnesium Hydroxide on Properties of HDPE¹¹²

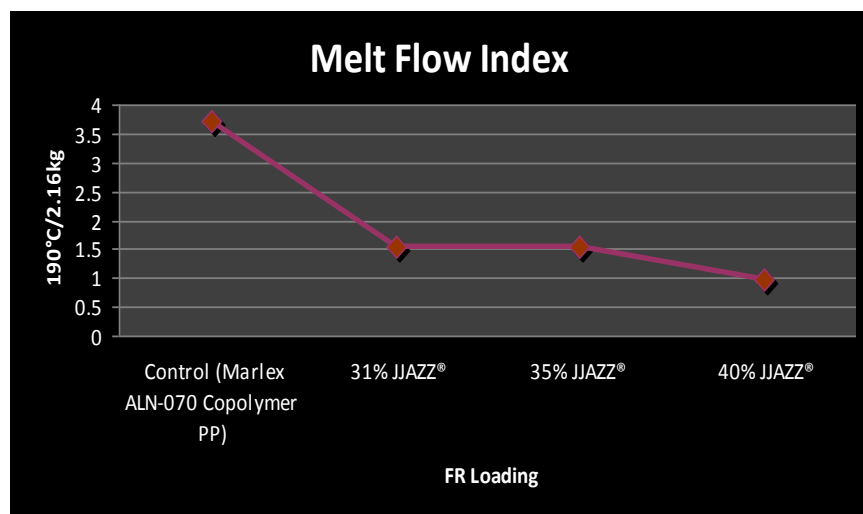
Magnesium Hydroxide % Concentrations	Melt Flow Index, grams/minute	Tensile Strength, Mpa¹¹³
0	7.0	23.0
35	5.4	24.9
40	4.0	24.7
45	2.2	24.3
50	1.2	23.0
55	0.8	22.5
60	0.2	21.8
65	0.1	20.0

¹¹² "Compounding High Flame Retardant Chemicals Into Polymers" James Innes & A W Cox Flame Retardants Associates presented at Flame Retardant Chemicals Association 10/26/97

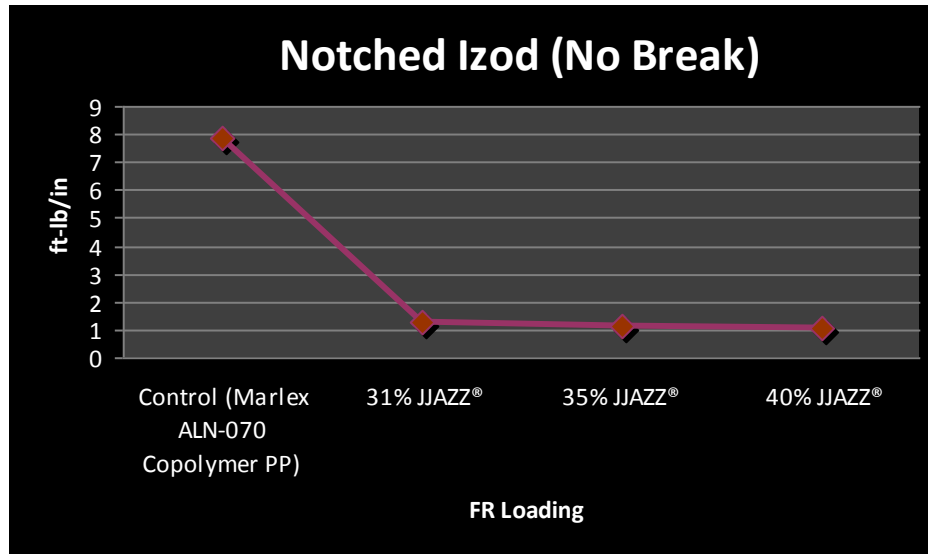
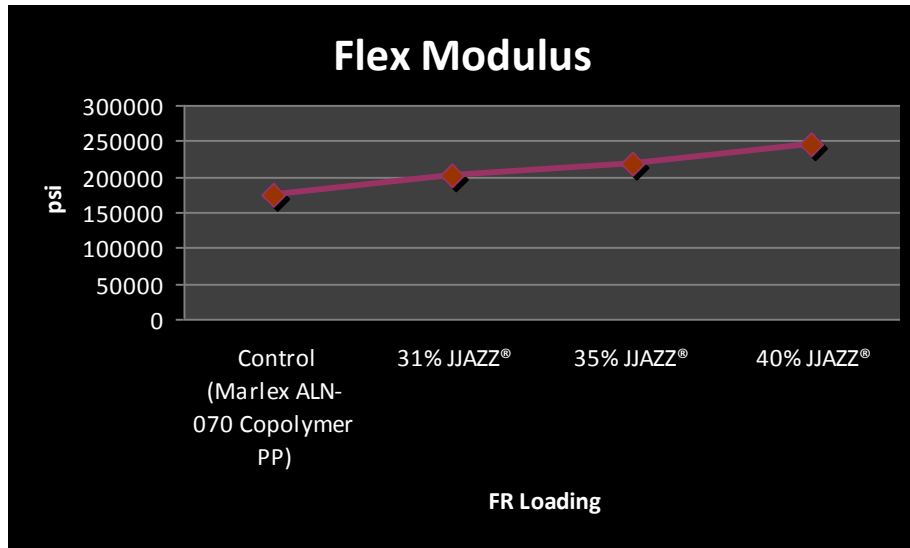
¹¹³ Mpa is the abbreviation for the megapascal unit of measurement.

Another example of how non-halogenated flame retardants affect the physical properties of a plastic is shown by the graphs in Figure 3.2. They illustrate the deleterious effect of increasing concentrations of JJI's JJazz amino phosphate flame retardant on melt flow, impact resistance and flex modulus (a measure of stiffness/resistance to breaking) of a polypropylene with a Melt Flow Index of 7.¹¹⁴ The graph of the Melt Flow Index shows how increasing the concentration of JJAZZ reduces the melt flow index of the polymer, just as in the previous magnesium hydroxide example. The second graph, Flex Modulus, shows that increasing the concentration of JJAZZ also is coincident with an increase in modulus, or stiffness. Pallets need to be stiff, but if excessively stiff, they break too easily. The third graph, Notched Izod, shows the plastic compound's brittleness; when the level of JJAZZ increases, far less impact is required to break the plastic. A brittle pallet can shatter when dropped or shocked by a fork lift. Thus increased concentrations of the JJAZZ amino phosphate flame retardant are associated with reduced processability and increased stiffness and brittleness.

Figure 3.2: Impacts of Amino Phosphate Flame Retardant on Properties of Plastic Polymer



¹¹⁴ "Innovative and Novel Non-Halogen Flame Retardants" by Nicholas A. Zaksek, Manager of Applications Research and Development, JJI Technologies.



Devising solutions to the technical difficulties of making a workable non-halogenated flame retardant pallet is a major task. But it is made even more challenging by the need to meet the cost constraints of a highly competitive market. We will explore this issue in the next chapter.

Chapter IV: Costs

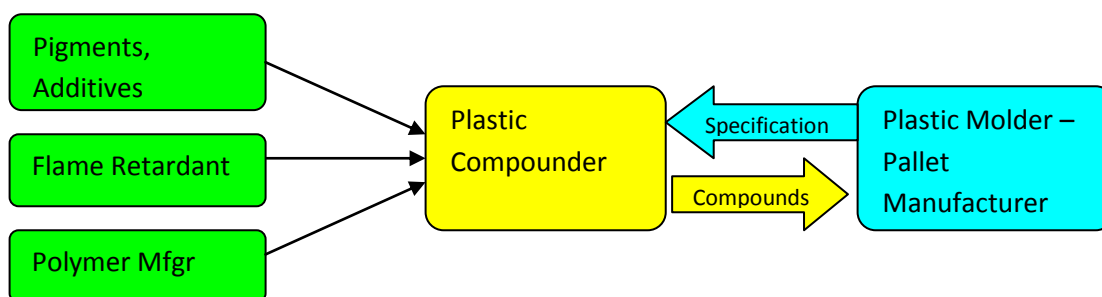
In designing a new plastic pallet with an alternative, non-halogenated flame retardant to replace the use of decaBDE, developers not only face an array of daunting formulation challenges in balancing the demands of flame retardancy and other physical attributes for a plastic pallet as discussed in the last chapter, but also major cost concerns. Cost pressures include both the development process itself and the ultimate cost of the pallet in the marketplace. This chapter will provide a brief overview of some of the roles and costs involved in the development process, and the interplay of cost and physical parameters in constraining the alternatives in the development of a non-halogenated fire retardant plastic pallet. One important bottom line is that a shipping pallet is not a premium-price product. The best pallet money can buy is likely to be far too costly for the real market. So developers need to balance not only the effectiveness of a flame retardant/polymer compound in reducing the pallet's flammability while maximizing essential strength, stiffness, durability and functionality goals, but to achieve this technical balancing act while recognizing that a pallet is a commodity product. Cost matters.

Costs for the new pallet include the costs of the development process, and the recurring costs built into the design and materials for the blend of flame retardants and polymers selected.

Costs in the Process of Designing and Developing a Plastic Pallet

Designing a new pallet and bringing it to market requires a large investment by the manufacturer. Figure 4.1 below depicts some of the key activities in design and production.

Figure 4.1: Pallet Manufacturing Flow Diagram



As Figure 4.1 shows, there are several contributors to the process of designing a new pallet. The pallet manufacturer, with the molding equipment that will be used to produce the pallet, sends a set of specifications for a flame retardant plastic pallet to the plastic compounder. The compounder develops a formula for the ingredients of the plastic *compound* containing polymers, flame retardant(s) and other performance enhancement additives that, when mixed in the proper proportions and molded, will produce a plastic pallet that meets the key pallet performance properties specified by the pallet manufacturer. For the compounder, the balancing act in meeting the manufacturer's specifications will involve finding a combination of ingredients that yields a plastic compound with physical properties that correspond to acceptable pallet performance characteristics shown in Table 3.1 of the last chapter. Table 4.1 shows the relationship between physical properties of the plastic compound and pallet attributes.

Table 4.1: Challenges for the Compounder: Balancing Physical Properties

<u>Physical Properties</u>	<u>Definitions</u>	<u>Relationship to Pallet Attributes</u>
Specific Gravity	The weight of a substance divided by the volume it occupies at a standard temperature and pressure	The higher the specific gravity the heavier the pallet. This is a critical pallet cost factor, and will be discussed in more detail in the next section of this chapter.
Modulus	A measure of stiffness or resistance to bending, determined by a bending test	Related to how a pallet withstands bending under stress -- a key property for indicating the "Rack Load Capacity"
Impact Resistance	The relative susceptibility of plastics to fracture under impact stresses applied at high speeds	Fracturing under impact stresses relates to brittleness; a pallet is tested for brittleness via a drop test.
Deflection	A measure of the deformation of a plastic under stress.	Deflection relates to the dimensional changes in a pallet when subjected to heavy static loads.
Melt Flow	Measure of the flow of a molten plastic under heat and pressure.	This is a key indicator of the processability of the plastic during the pallet manufacturing process.
Flame Resistance	Ability of a compound of flame retardant to reduce a polymer's flammability	Ultimately, the goal is to design a pallet that can pass the UL 2335 or FM 4996 tests.

As the graphs from JAZZ illustrate (see Figure 3.2), the effects of the flame retardant may undermine the other needed attributes to varying degrees. There is no guarantee that a given flame retardant mixture will be effective at a low enough level to avoid under-cutting performance on the other attributes. Finding the right mix for a new, non-halogenated flame retardant, if successful, may involve a lengthy process of iterative testing. As the development process continues, there are a number of key hurdles, some of which have potentially high costs.

- After one or more promising candidate mixtures is developed, batches of compound will be made to make one or more pallets in the compounder's production mixing equipment and the pallet manufacturer's production molding equipment. If a compound successfully processes in the molding equipment, then the compounder will make a bigger batch of compound – enough to make 10, 20 or 50 pallets. This will test the compound's processability in production equipment. Ultimately, processability of a compound is a potentially significant cost issue, a matter of the maximum achievable production rate while maintaining product quality. For example, if a compound made with a nonhalogenated flame retardant were to have a production rate of 20 pallets/hour while a compound made with decaBDE had a production rate of 35-40 pallets/hour, then there would be a significant economic disparity.¹¹⁵ This disparity would have to be compensated for with a lower price for other factors in pallet production.
- The best performers of the pallets made from a test batch of compound may be sent to UL for medium-scale idle pallet testing. This testing can cost as much as \$10,000 for each iteration.¹¹⁶
- If a compound satisfies all of the criteria for making a flame retardant plastic pallet in production equipment, then a larger batch of compound is produced so the pallet manufacturer can submit the necessary number of pallets for the large scale fire tests which can cost as much as \$100,000. Failure requires reformulation, going through many of the steps all over again.¹¹⁷
- If successful, the pallet manufacturer orders a small production run of pallets for test marketing. The test marketing program may fail to generate enough income to cover the costs of the pallets made for the program.

The development and testing process has many uncertainties and, at the end of the process, no guarantee of success. But the key cost parameter is more likely to be the recurrent costs of production built into the flame retardant/polymer compound used to make the pallet.

¹¹⁵ Personal communication with Bruce Torrey, iGPS, November 28, 2010. The production rate is based on producing 300,000 pallets per year operating 8,000 hours per year, or nominally 24/7. This was a hypothetical production rate supplied by iGPS to illustrate the effect of processability on production rate.

¹¹⁶ Personal communication with Bruce Torrey, *ibid.*

¹¹⁷ Personal communication with Bruce Torrey, *ibid.*

Materials and Pallet Costs

*The Cost Factor and Flame Retardant Plastic Pallets*¹¹⁸

A key property of plastic compounds that directly affects the cost factor is specific gravity. Specific gravity can be defined as the density (mass per unit volume) of any material divided by that of water at a standard temperature (usually 4°C). Standard industry practice is to use specific gravity as a measure of density. What does this mean? For a given volume of material, a plastic compound with a lower specific gravity will produce a part with lower weight; it takes fewer pounds of material to fill a mold to produce the part. A given amount of a plastic compound or formulation with a lower specific gravity will produce more parts than another formulation with a higher specific gravity. **Molds are filled on a volume basis, not by weight.** One of the resulting “tricks of the trade” is knowing that a less costly formulation which meets all the part’s requirements across the board may simply not be economically attractive if its specific gravity is too high. In other words, needing more of the compound to fill the mold often wipes out the advantage of the lower cost per pound.

Comparing Flame Retardant Compounds

The data in Table 4.2 illustrate how various flame retardants affect the specific gravity of a plastic compound. The data was derived from assorted product information sheets and technical papers on flame retardants incorporated in polyolefins. For the purpose of this table, the specific gravities of various grades of polypropylene are assumed to be essentially equivalent. All of these formulations were designed to make corresponding plastic compounds that would yield a V-0 rating on a UL-94 flame test.¹¹⁹ Underwriters Laboratory (UL) has established ignition-resistance classifications for plastics ranging from HB (least resistant) to V-0 (most resistant). UL-94 test protocol is a useful tool for screening flame retardants for plastic compounds in the early stages of formulation development. The test yields rudimentary data on the flammability of a material which can be used for comparing flame resistance of candidate flame retardants. Beyond that, there is no correlation of UL-94 test data with test results obtained using the UL 2335 or FM 4996 test protocols.¹²⁰ So once the preliminary candidacy of a flame retardant has

¹¹⁸ This subsection of the report was prepared for this report by James Innes & Ann Innes of Flame Retardants Associates.

¹¹⁹ UL 94 is a small scale cone calorimeter used to evaluate the effect of flame retardants on flammability of a plastic. For more information on UL-94, see Appendix VIII.

¹²⁰ The fact that a small piece of plastic with a flame retardant compound meets even the highest-level UL-94 test level does not answer the question of what will happen to that same material in the dynamics of a large fire or in response to the water from a sprinkler system.

been established with UL-94 laboratory test data, the major work in testing, including preparation of enough material to make full size pallets for initial large scale fire tests, remains to be done.

Table 4.2: Polypropylene/Flame Retardant Compounds¹²¹

Flame Retardant Type	No Flame Retardant ¹²²	DecaBDE	Ammonium Polyphosphate System	Amino Phosphate/proprietary amines	Magnesium Hydroxide
Polypropylene (PP)	100%	63%	63%	65%	45%
Flame Retardant		26%	37%	35%	65%
Antimony oxide		11%			
Total FR content	0%	37%	37%	35%	65%
Specific gravity	0.901	1.27	1.07	1.02	1.5

Table 4.2 shows that each of the flame retardants increases the specific gravity of the polypropylene compound. A PP compound made with decaBDE increases its specific gravity by 40%, ammonium polyphosphate by 18% and magnesium hydroxide by 66%. Therefore the cost of using less expensive flame retardants has to be tempered by the cost of using a greater weight of plastic compound to fill the mold. Both of the phosphate flame retardants have the lowest impact on specific gravity of the plastic compounds and they impart credible flame retardance. This information suggests phosphates should be considered as viable alternatives for decaBDE in plastic pallets.

For magnesium hydroxide, the level of flame retardant required in a polypropylene polymer to gain UL 2335 certification and/or FM 4996 approval, is somewhat less than 25%. To meet a similar requirement with a decaBDE compound requires a little over 10%. When the specific gravity and cost of each flame retardant is calculated using these lower required flame retardant levels, the cost per pound for each is similar, with

¹²¹ Data on all of the flame retardants was taken from the report by Sergei Levchik et al "Flame Retardants for Polypropylene," ICL Industrial Products.

¹²² Data on polypropylene was taken from the report by Nicholas A. Zaksek of JJI Technologies "Innovative and Novel Non-Halogen Flame Retardants."

a slight advantage for the magnesium hydroxide compound. This suggests that magnesium hydroxide is also a viable alternative to decaBDE. To examine the complete analysis and calculations, see Appendix VI.

Chapter V: Alternative Non-Halogenated Flame Retardants

Previous chapters have reviewed the challenges of balancing flame retardancy, pallet performance characteristics and costs in bringing non-halogenated (NH) plastic pallets to market. But pallets with two different non-halogenated flame retardant systems are already on the market, and more may well be on the way with some companies in the process of planning FM or UL tests. Much of the information on current developments is proprietary, so we can't know for sure what alternatives are under development. Goals for the present study include bringing together non-proprietary information on alternative nonhalogenated flame retardants, and ensuring that the development of alternatives to decaBDE does not lead to unfortunate toxicological choices. This chapter will briefly bring together and review the information on potential non-halogenated flame retardants. The most promising of these have been selected for review under the Green Screen chemical toxicology assessment methodology developed by Clean Production Action. Chapter 6 will then present a description of the Green Screen methodology and a report on the results of the individual chemical assessments.

*An Overview of Non-Halogen Flame Retardants in Plastic Pallets*¹²³

Fire resistant pallets have been successfully produced using one or more non-halogenated flame retardant chemicals and the pallets have been tested and certified by UL and FM as equivalent to wood. The issues with non-halogen flame retardants in plastic pallets, as discussed in the preceding chapters, relate primarily to cost and the adverse effects on physical properties that can occur when such flame retardant compounds are incorporated into a plastic matrix.

The following discussion of the potential for using nonhalogenated flame retardants as alternatives to decaBDE explains the strengths and weaknesses of the nonhalogenated flame retardants that: i) were identified as being feasible for use in polyolefins, the preferred plastic for making pallets; and ii) have been used successfully in plastic applications other than pallets.

¹²³ Most of this section of Chapter V was prepared for this report by James Innes & Ann Innes of Flame Retardants Associates. The only exceptions are the second part of the subsection on magnesium hydroxide, and the subsections on melamine polyphosphate and melamine cyanurate.

Inorganic Metal Hydroxides

This is a class of flame retardants that is low in cost but requires high concentrations in plastic pallets to meet the criteria for UL 2335 and/or FM 4996. Therefore, the advantage of low unit cost is lost to the high concentrations of flame retardant.

Mg(OH)₂ (Magnesium Hydroxide)

Magnesium hydroxide is a compound that contains 31% chemically bound water. This water-insoluble compound, when dried and incorporated into a plastic polymer matrix, will form a composite. When exposed to fire, the composite first gives off chemically bound water (which cools the composite) at about 300 °C. After the water is released, a protective magnesium oxide (MgO) refractory layer is left behind which provides additional flame retardancy and an “anti-pooling” effect necessary in the idle pallet test. This flame retardant chemical is a heat absorbing type flame retardant. For a flame retardant plastic pallet application, the magnesium hydroxide would be incorporated into a polyolefin resin at about 23% loading.

In its powder form, magnesium hydroxide can be treated with particle treatment chemicals to improve its compatibility with the polymer matrix. The particle treatment chemicals include stearic acid and vinyl triethoxy silane. The particle treatment process allows for a better dispersion of the flame retardant in the polymer matrix and consequently better processability.

Rehrig Pacific has a patented, commercially available magnesium hydroxide-based flame retardant polypropylene plastic pallet. It incorporates about 23% magnesium hydroxide, in combination with aluminum trihydroxide and zinc borate, in a polypropylene polymer to pass the flammability requirements, and has a UL2335 listing.¹²⁴

Aluminum trihydrate

Aluminum trihydrate (ATH) is also a compound with 34% chemically bound water. It works in the same fashion as magnesium hydroxide except that the water is released from ATH at a lower temperature, about 200 °C. This effectively limits its application to lower temperature polymers, and for plastic pallets that means ATH is suitable only for HDPE, not PP. Loading levels are the same as Mg(OH)₂ at about 23%. This one is also considered a heat absorbing type of flame retardant.

¹²⁴ [United States Patent: 7252041](#) “Flame retardant polyolefin pallets and flame retardant master batch for their production.” Personal communication from Mike Lochner, Rehrig Pacific, November 19, 2010.

Major suppliers of ATH include Albemarle Corporation and Huber Engineered Materials with products under trade names such as Martinal®, Micral®, and Hymod®.

The authors are unaware of any idle pallet testing at either UL or FM on ATH-containing flame retardant plastic formulations.

Zinc Borate

Zinc borate (ZB) is an inorganic (no carbon) additive. When incorporated into the ATH or $Mg(OH)_2$ flame retardant systems, zinc borate produces an increased flame retardant effect. ZB is produced by reacting Borax (known to many via the 20 Mule Team brand) and zinc oxide. This is a powder product usually incorporated into the flame retardant system at 10-15% of the metal hydrate quantity used. When the composite is subjected to fire insult (exposure to fire according to test protocol) and the metal hydrate has formed the oxide, the ZB and that oxide combine to form a borate glass. This action increases the protection that the oxide layer provides. ZB is largely supplied by one company, US Borax, (Englewood, CO, owned by Rio Tinto) and marketed under the trade name Firebrake®. As with ATH, this technology modification is not known by the authors to have undergone idle pallet testing at either UL or FM.

Phosphates

Ammonium Polyphosphate

Ammonium polyphosphate (APP) is produced by the reaction of ammonium hydroxide and polyphosphoric acid to form an essentially insoluble ammonium phosphate. APP has been used as a flame retardant for polyolefins for over 30 years. In order to be effective as a polyolefin flame retardant, APP must be compounded with melamine and a product such as pentaerythritol, which acts as a carbon donor. The usual ratio of these components is 3:1:1. This product is typically compounded into the polyolefin at a concentration of about 12% to form a composite. When subjected to fire, the APP in the composite breaks down into a polyacid which chars the pentaerythritol. During the process, the melamine sublimates (goes directly from the solid to gas phase) causing the whole mass to intumesce. This intumescent (swollen) char insulates the remaining composite helping to mitigate additional heat insult from the fire. This flame retardant system effectively removes the fuel from the fire triangle picture and thus could be considered a char-forming type of flame retardant.

Suppliers include Budenheim (Spain), Clariant (Germany) and ICL (Israel, with USA operations in St. Louis, MO). Trade names for these producers' APP products include respectively flame retardant CROS, Exolit®, and Phos-Chek P/30.

Ethylene diamine phosphate

Ethylene diamine combines with phosphoric acid to form ethylene diamine phosphate (EDAP). This compound has been offered as a flame retardant for polyolefin for over 20 years. Initially, it was offered by Albright & Wilson, later acquired by Rhodia. They discontinued their product, Amgard NP, and its manufacture was taken up by other producers. To be an effective flame retardant, EDAP is typically combined with melamine at a ratio of about 3 to 1. This product is incorporated into the polyolefin composite at about a 12% loading to meet the perceived required level for the idle pallet test. When subjected to fire insult, the EDAP decomposes first to phosphoric acid which then dehydrates (loses water) to a polyacid and, in the presence of pentaerythritol, produces char. During this process the melamine sublimates to provide intumescent action. This flame retardant is also considered a char former type of flame retardant.

Suppliers include JJI Technologies (Painesville, OH) and Unitex Chemical Corporation (Greensboro, NC). Trade names for EDAP from these companies are JJAZZ® and Uniplex® 44-94S.

Industry experts informed us that no formulations of the EDAP product or its combinations with melamine have been developed which meet UL or FM pallet standards. According to J. Day of Unitex,¹²⁵ the sell price of the blended system today is in the range of \$2.00-\$2.25/pound.

Melamine Polyphosphate

Melamine phosphates (MPP) are salts of melamine and phosphoric acid. These salts have good properties of thermal stability and are commonly used as flame retardants. Melamine and its derivatives (cyanurate and phosphates) are currently used in flexible polyurethane foams, intumescent coatings, polyamides, and thermoplastic polyurethanes. MPP meets the requirements for reporting for REACH¹²⁶ & RoHS.¹²⁷ When used with polyamides it is easy to process, eliminating the need for special

¹²⁶ REACH (Registration, Evaluation, Authorization and Restriction of Chemical substances) is a European Community Regulation on chemicals and their safe use ([EC 1907/2006](#)). It became effective in 2007.

¹²⁷ RoHS (Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations) is a European Community regulation which first became effective in 2006. www.rohs.eu.

extruder screws. It has good heat stability with a decomposition temperature of 330°C.¹²⁸

Melamine Cyanurate

Melamine cyanurate, is a salt of melamine and cyanuric acid. Melamine cyanurate has a higher thermal stability than pure melamine, with decomposition starting at 320 °C. Melamine cyanurate is often used as a flame retardant in polymers with higher melting temperatures, such as polyamides. Above 320°C, it undergoes endothermic decomposition to melamine and cyanuric acid, acting as a heat sink in the process. The vaporized melamine acts as an inert gas source diluting the oxygen and the fuel gases present at the point of combustion.

Due to the high decomposition temperature, melamine cyanurate is primarily used in engineering plastics such as nylon, polyphenylene oxide, and ABS.¹²⁹

Melamine cyanurate is manufactured by ICL and U.S. Chemicals.

Phosphate Esters

Phosphate ester flame retardants include a group of chemical compounds which each has a different chemical structure. All are produced by the reaction of phosphorus oxychloride with an aromatic¹³⁰ organic compound. (Examples include trialkylated phenol phosphate or bisphenol A diphosphate.) In the flame retardant pallet application, the resin that is incorporated is not polyolefin, but MPPO (also known as Noryl®) which is a product made from modified polyphenylene oxide and high impact polystyrene (HIPS). Loading level ranges from 6-8%. When the MPPO is plasticized with the phosphate ester and is subjected to fire insult, the initial mechanism is a breakdown of phosphate ester into a polyacid which chars and protects the underlying substrate. There is a significant gas phase, radical-trapping mechanism occurring here, as well, with phosphorus aromatic compounds released during the pyrolysis (burning) process. So this type of flame retardant system can be considered a char-former type with a radical trapping mechanism as well.

Phosphate ester flame retardant products are supplied by Chemtura (Lafayette, IN), Daihachi Chemical Industry Company (Japan), and ICL Supresta (Dobbs Ferry, NY). Trade names include Reofos®, Kronitex®, CR733S, and Phosflex®.

¹²⁸ Information on melamine polyphosphate was supplied by ToxServices (see Appendix IX)

¹²⁹ Information on melamine cyanurate was supplied by ICL corp.

¹³⁰ Aromatic compounds are organic compounds that have a ring structure with resonating double bonds that makes them extremely stable. The most common example is benzene.

Selection of Alternatives to Review

The effectiveness and relatively low cost of using decaBDE as a flame retardant in plastic pallets has served, in the past, as a disincentive to development of plastic pallets using nonhalogenated alternative flame retardants. But the combination of state restrictions on decaBDE and US EPA's voluntary agreement with manufacturers to bring sales of decaBDE to an end dramatically shifts those incentives. The previous chapters have explored both the technical and cost challenges of developing new alternatives. In a highly competitive market dominated by a low cost alternative, overcoming these barriers is difficult. It is reasonable to ask whether design, development and flame retardancy testing costs can be recovered, or whether the market would accept the higher price of an alternative non-halogenated flame retardant plastic pallet. Maine's new restrictions on the use of halogenated flame retardants in pallets has not eradicated those constraints, but probably alleviates them. They also provide a market opportunity for the pallet manufacturer with the best answer to the puzzle. While too much of the information is proprietary to be sure what new flame retardants may be coming to market, it seems probable that new flame retardant compounds with non-halogenated alternatives will be emerging.¹³¹

While there is no way to be certain which alternatives have greatest promise or are currently being developed or tested, we have used the information from the many sources presented in this and previous chapters to select some that seem the most promising (Table 5.1) for toxicological review with the Green Screen methodology. The results of the assessments of these non-halogenated flame retardants, along with a comparative assessment of decaBDE, are presented in the next chapter.

¹³¹ As noted in Table 2.4, there are currently two pallets with non-halogenated alternatives that have passed the UL 2335 or FM 4996 tests, one of which is on the market and the other of which just began production in December 2010. Comparisons with a decaBDE flame retardant pallet can be found in Chapter VII.

Table 5-1: Non-Halogenated Flame Retardants Selected for Review with Green Screen

Flame Retardant	CAS#	Reason for Selection
Melamine polyphosphate	218768-84-4	Recommended by PINFA ¹³² .
Ethylenediamine phosphate	14852-17-6	Demonstrated FR properties for polypropylene
Ammonium polyphosphate	68333-79-9	Excellent general purpose FR but recommended for use with synergists
Red phosphorus	7723-14-0	Demonstrated application in thermoplastics
Magnesium hydroxide	1309-42-8	Demonstrated FR properties in thermoplastics and is currently being used in a polypropylene pallet
Aluminum trihydroxide	21645-51-2	Demonstrated FR properties in PE but not in PP
Zinc Borate	138265-88-0	Useful as a supplemental FR with ATH and Magnesium Hydroxide
Magnesium stearate	557-04-0	Magnesium hydroxide particles treated with stearate acid to facilitate a better dispersion of magnesium hydroxide in a polymer matrix

¹³² Phosphorus, Inorganic and Nitrogen Flame Retardants Association

Chapter VI: Flame Retardant Toxicity Assessments¹³³

This chapter evaluates health and environmental hazards and assigns Green Screen hazard ratings to the flame retardant decabromodiphenyl ether (decaBDE) and eight alternate flame retardants using Clean Production Action's (CPA) Green Screen (Version 1.0)¹³⁴¹³⁵. For each flame retardant, endpoints relating to human health effects, aquatic toxicity, and environmental effects were evaluated, and each endpoint was assigned a score of Low hazard (L), Moderate hazard (M), High hazard (H), or very High hazard (vH).

CPA's Green Screen is an Alternatives Assessment tool developed to assist the industry in selecting safer chemical alternatives. Alternatives Assessment is an approach used to assess a chemical's impact on human health and the environment. The goal is to find a science-based solution that identifies hazards, and as a result, promotes the selection of less hazardous chemical ingredients.

The following are procedures used by Green Screen in an Alternatives Assessment:

- To determine the need for and potential benefits of an alternatives assessment, the reviewer considers whether alternatives are commercially available and cost effective; whether alternatives have the potential for an improved health and environmental profile; and whether they are likely to result in lasting change.
- Through literature review and discussion with stakeholders, information is collected about viability on a range of potential alternatives. The focus is on finding alternatives. The reviewer may also include viability demonstrations by chemical and product manufacturers.
- Based on the best data that are available from the literature or that can be modeled, a hazard concern level is assigned (High, Moderate or Low) for each alternative across a range of endpoints including: acute and repeated dose toxicity; carcinogenicity and mutagenicity; reproductive and developmental toxicity; neurotoxicity; sensitization and irritation; acute and chronic aquatic toxicity; persistence; and bioaccumulation. In addition, a qualitative description of potential endocrine activity may be assigned.

Sources of information for a hazard assessment include one or more of the following:

¹³³ This Chapter prepared by scientific consulting firm ToxServices.

¹³⁴ Clean Production Action (CPA). The Green Screen for Safer Chemicals, Version 1. September, 2009.

¹³⁵ CPA recommends independent third-party validation of all Green Screen assessments. No independent third-party validation has been done for this report. Companies may not make marketing claims based on a Green Screen assessment that has not undergone an independent validation.

- Publicly available measured (experimental) data obtained from a literature review;
- Measured data contained in confidential business information received by EPA;
- Structure-Activity-Relationship- (SAR) based estimations from EPA's Pollution Prevention Framework and Sustainable Futures predictive methods;
- Confidential data in experimental studies supplied by the chemical manufacturers.

When measured data are not available or adequate for an endpoint, a hazard concern level can be assigned based on SAR and expert judgment. This practice ensures that all endpoints are considered as part of the hazard assessment and that alternatives are evaluated based on as complete an understanding of their human health and environmental characteristics as possible. A level of confidence associated with hazard assignments is assigned.

Once the hazard assessment is complete, an Alternatives Assessment report is written to provide contextual and supplemental information designed to aid in decision-making and may include descriptions of manufacturing processes, use patterns, and life-cycle stages that may pose special exposure concerns.

Green Screen Screening Methods

The Green Screen is a comparative hazard assessment tool that manages chemical risk by reducing hazards rather than controlling exposure to potentially toxic chemicals.¹³⁶ Hazard assessment is the process of determining whether exposure to an agent can cause an increase in the incidence of adverse health effects (such as an allergic reaction, birth defect, or cancer), and involves a characterization of the nature and strength of the evidence of causation¹³⁷. A comparative hazard assessment evaluates hazards from two or more agents, with the intent to guide decision making toward the use of the least hazardous options via a process of informed substitution.

In practical terms, comparative hazard assessment is a term that describes the practice of assessing hazards for specific items (such as chemicals or technologies), and then comparing these hazards following a structured approach. Ideally, comparative hazard assessment minimizes subjectivity in hazard classification since a structured approach is

¹³⁶ Clean Production Action. 2010. Clean Production Action's Green Screen.

<http://www.cleanproduction.org/Greenscreen.php>

¹³⁷ Kofi Asante-Duah, D. 1993. Risk assessment techniques and methods of approach. In Hazardous Waste Risk Assessment. Chelsea: Lewis Publishers, pp.59-158.

used to assign hazards, allowing decision makers to optimize health and environmental benefits.

The Green Screen for Safer Chemicals is a quantitative chemical screening method designed to help manufacturers identify inherently less hazardous chemicals using a standardized approach that considers both human health and environmental effects. As part of a Green Screen evaluation process, each ingredient or chemical is assigned a Concern Level. Individual hazards are evaluated for almost one dozen hazard endpoints (such as carcinogenicity, reproductive toxicity, neurotoxicity, aquatic toxicity, persistence, and bioaccumulation) and then a hazard rating of very High, High, Moderate, or Low is assigned for each endpoint for each chemical. The Concern Levels are then collectively evaluated in Green Screen Version 1.0 to one of four different benchmark scores, as illustrated below in Figure 1:¹³⁸

- Benchmark One: Avoid (Chemical of High Concern)
- Benchmark Two: Use (But Search for Safer Substitutes)
- Benchmark Three: Use (But Still Opportunity for Improvement)
- Benchmark Four: Prefer (Safer Chemical).

For each flame retardant evaluated in this report, endpoints relating to human health effects, aquatic toxicity, and environmental effects were evaluated following the criteria established in Green Screen Version 1.0.¹³⁹ As noted above, the Green Screen identifies the following health effects: acute toxicity; corrosion/irritation; sensitization; systemic toxicity; carcinogenicity; mutagenicity; reproductive/developmental toxicity; endocrine disruption; or neurotoxicity.

Authoritative lists specified in CPA's Hazard Threshold Table (dated 11/01/2009) were searched for each chemical listed,¹⁴⁰ as was the CPA Red list of chemicals dated May 13, 2009.¹⁴¹

In instances where a large data gap exists for a chemical (either for a health effect or environmental effects endpoint), one or more structurally similar surrogates are analyzed for that particular endpoint. This approach is based on the assumption that a chemical's structure imparts properties that relate to biological activity, and that a group of chemicals that produce the same activity have something similar about their

¹³⁸ Clean Production Action. 2010. Clean Production Action's Green Screen. <http://www.cleanproduction.org/Greenscreen.php>

¹³⁹ Clean Production Action (CPA). The Green Screen for Safer Chemicals, Version 1. September, 2009.

¹⁴⁰ Clean Production Action (CPA). Green Screen Hazard Threshold Table, Version 1. November 3, 2009.

¹⁴¹ Clean Production Action (CPA). Red list of chemicals. May 13, 2009.

chemistry and/or structure.¹⁴² Chemicals produced by similar methods by the same company and used for similar purposes make good potential analogs. In addition, degradation products of the parent compound can be used as surrogates especially if the parent compound is expected to break down readily in the environment. The Organization of Economic Co-operation and Development (OECD)¹⁴³ and U.S. Environmental Protection Agency (U.S. EPA)¹⁴⁴ have defined guidelines for identifying similar substances to use analogs based on the following commonalities:

- A common functional group or substance (e.g. phenols, aldehydes);
- A common precursor or break-down product may result in structurally similar chemicals, which can be used to examine related chemicals such as acids/esters/salts (e.g. short-chained alkyl-methacrylate esters which are metabolized to methacrylic acid);
- An incremental or constant change (e.g. increased carbon chain length; typically used for physiochemical properties such as boiling point); and
- Common constituents or chemical class, similar carbon range numbers (used with substances of unknown or variable composition), complex reaction products or biological material.

CPA's Green Screen Version 1.0 was initially developed to assess only organic chemicals. Because most inorganic chemicals contain covalent bonds, they do not break down readily and are likely to persist in the environment for longer periods of time. Persistence alone does not indicate a chemical is hazardous. Chemicals that are persistent as well as bioaccumulative and toxic are of high concern as their concentrations in the environment increase over time, allowing for more opportunity to exert a toxic effect on human health. Version 1.0 criteria states that a score of High for persistence results in an automatic Benchmark score of 2 (Use but Search for Safer Substitutes). Version 2.0 will be expanded to address inorganics such as mineral oxides

¹⁴² United States Environmental Protection Agency (U.S. EPA). 2010. Predicting the Toxicities of Chemicals to Aquatic Animals Species.

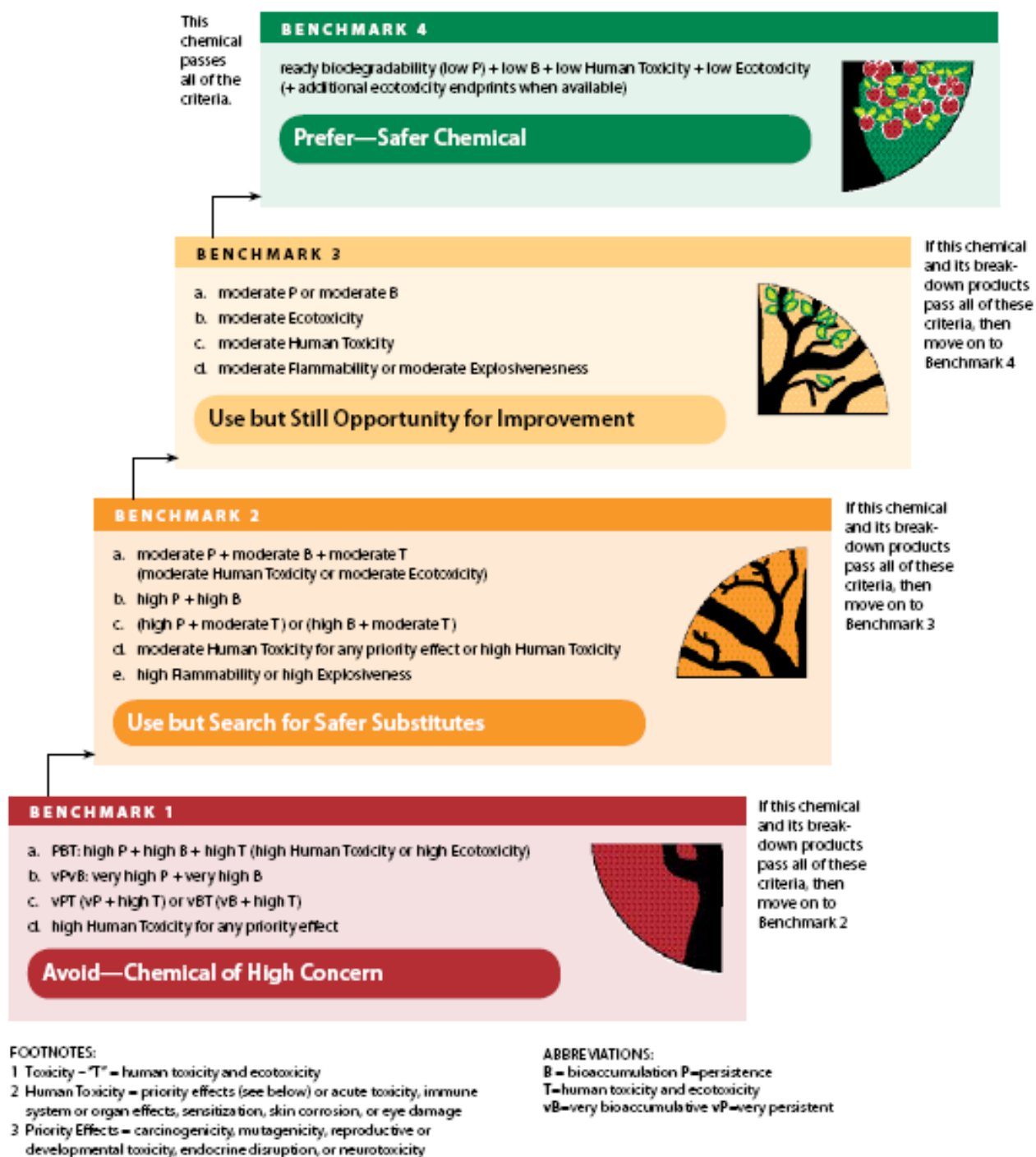
http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/aqlife/upload/whitepaper_effects.pdf.

¹⁴³ Under the guidelines published by Organisation for Economic Co-operation and Development (OECD), an analog selected to fill a data gap must be data rich and share similar physical and chemical properties, including behavior in physical or biological process, with the original compound. Organisation for Economic Co-operation and Development (OECD). 2007. Guidance on Grouping of Chemicals. OECD Environment Health and Safety Publications. Series on Testing and Assessment No. 80.

¹⁴⁴ U.S. EPA. 2010. Predicting the Toxicities of Chemicals to Aquatic Animals Species. http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/aqlife/upload/whitepaper_effects.pdf

to allow for comparison of inorganic chemicals used as flame retardants. Under Version 2.0 criteria, an inorganic chemical with a Low hazard rating for human and ecotoxicity across all hazard endpoints and a Low hazard rating for bioaccumulation and persistence will not be deemed problematic. Inorganic chemicals that are only persistent will be evaluated under the criteria for Benchmark 4.

Figure 6.1: CPA Green Screen Benchmark Scores (CPA 2009a)



Overview of Chemicals Profiled

This report evaluates health and environmental hazards posed by decaBDE, as well as hazards posed by eight alternative flame retardants: aluminum trihydroxide, ammonium polyphosphate, ethylenediamine phosphate, magnesium hydroxide, magnesium stearate, melamine polyphosphate, red phosphorus, and zinc borate.

Chemical flame retardants are added to many day-to-day products to prevent or suppress ignition of a fire or to limit the spread of fire once ignition has occurred. Flame retardants can be categorized into two main groups: additive or reactive.¹⁴⁵ The majority of flame retardants are of the additive type which can be added to a manufactured product without being chemically bound to it. This makes them less effective than reactive flame retardants which are incorporated into the final product during manufacturing. Flame-retardant synergists are an additional category of chemicals that do not have significant flame-retarding properties by themselves; however, their use increases the overall effectiveness of a flame-retardant system.

Additive flame retardants can be further classified as either halogenated (compounds containing chlorine or bromine bonded to carbon) or non-halogenated. Ongoing research into less toxic flame retardants is focused on non-halogen alternatives which are less likely to persist in the environment and to bioaccumulate in organisms. They also have the benefit of degrading more readily, reducing their potential long-term impact on human health and the environment.¹⁴⁶

DecaBDE is a member of the structurally similar subset of brominated flame retardants called polybrominated diphenyl ethers (PBDEs). In PBDEs, there are ten possible sites for bromine to bind to the diphenyl ether backbone; decaBDE represents the full saturation of the molecule, meaning all ten sites are populated with a bromine atom. PBDEs are used as flame retardants in a variety of products including building materials, electronics, furnishings, polyurethane foams, and textiles.

Commercial decaBDE generally has a purity of 97%; common impurities include lower brominated diphenyl ethers such as nonabromodiphenyl ethers and octabromodiphenyl

¹⁴⁵ United States Environmental Protection Agency (U.S. EPA). 2005. Furniture Flame Retardancy Partnership: Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam. Volume 1. Design for the Environment (DfE).
<http://www.epa.gov/dfe/pubs/flameret/altrep-v1/altrepv1-f1c.pdf>

¹⁴⁶ Department of Ecology (DOE). 2008. Alternatives to DecaBDE in Televisions and Computers and Residential Upholstered Furniture. Washington State Department of Health Publication No. 334-181.

ethers. The lesser brominated PBDEs (i.e., those with fewer bromine atoms per molecule, such as the pentaBDE and octaBDE formulations that already have been removed from the market), are considered more toxic than the more brominated PBDEs (such as decaBDE), because lesser brominated PBDEs are more likely to bioaccumulate. Although decaBDE is a higher brominated PBDE, it is known to degrade into lower brominated diphenyl ethers readily via light and microorganisms making decaBDE a cause for concern for the flame retardant industry.¹⁴⁷

According to the Illinois Environmental Protection Agency (IEPA), PBDEs are being detected in soil, water, sediment, air, and animals and humans worldwide in increasing concentrations.¹⁴⁸ One study in particular showed a significant increase of decaBDE concentrations in peregrine falcon eggs from the northeastern U.S.¹⁴⁹ The most sensitive human health effects of PBDEs include liver, thyroid, reproductive/developmental, and neurological effects.¹⁵⁰ Currently, industry is in the process of phasing out the use of PBDEs as flame retardants due to adverse human and environmental health effects of the chemicals. Initially, legislation focused on the phase-out of penta- and octa- BDE; however, more initiatives are looking into alternatives to decaBDE as well.¹⁵¹ The sole U.S. manufacturer of pentaBDE voluntarily agreed to halt production following the European Union's (EU) ban of the chemical in 2004¹⁵². Since then, laws in 13 states including California, Connecticut, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, Minnesota, New York, Oregon, Rhode Island, and Washington have enacted or introduced legislation relating to PBDEs.¹⁵³

¹⁴⁷ Illinois Environmental Protection Agency (IEPA). 2007. Report on Alternatives to the Flame Retardant DecaBDE: Evaluation of Toxicity, Availability, Affordability, and Fire Safety Issues. A Report to the Governor and the General Assembly.

¹⁴⁸ Ibid.

¹⁴⁹ Chen, D., M.J. La Guardia, and E. Harvey. 2008. Polybrominated Diphenyl Ethers in Peregrine Falcon (*Falco peregrines*) Eggs from the Northeastern U.S. Environ. Sci. Technol. 42(20); 7594-7600. As described in: Department of Ecology (DOE). 2008. Alternatives to DecaBDE in Televisions and Computers and Residential Upholstered Furniture. Washington State Department of Health Publication No. 334-181.

¹⁵⁰ Illinois Environmental Protection Agency (IEPA). 2007. Report on Alternatives to the Flame Retardant DecaBDE: Evaluation of Toxicity, Availability, Affordability, and Fire Safety Issues. A Report to the Governor and the General Assembly.

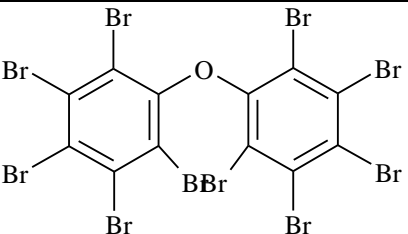
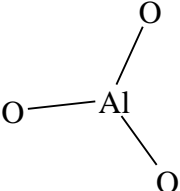
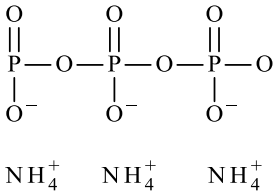
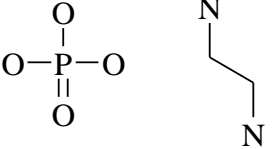
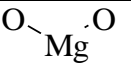
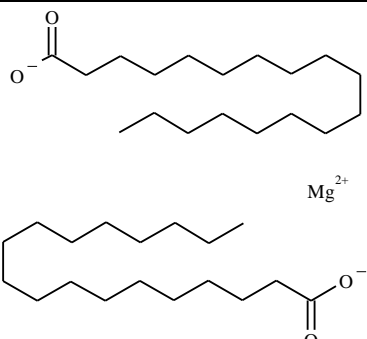
¹⁵¹ Ibid.

¹⁵² United States Environmental Protection Agency (U.S. EPA). 2005. Furniture Flame Retardancy Partnership: Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam. Volume 1. Design for the Environment (DfE). Available: <http://www.epa.gov/dfe/pubs/flameret/altrep-v1/altrepv1-f1c.pdf>

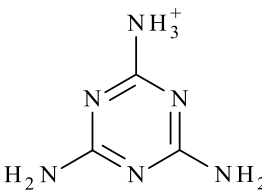
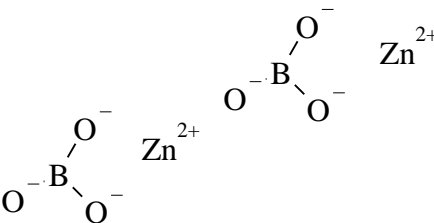
¹⁵³ Illinois Environmental Protection Agency (IEPA). 2007. Report on Alternatives to the Flame Retardant DecaBDE: Evaluation of Toxicity, Availability, Affordability, and Fire Safety Issues. A Report to the Governor and the General Assembly.

Washington, Maine, and Oregon have all proposed statutes restricting the use of decaBDE by January 1, 2010.

The nine flame retardants are illustrated in Table 6.2 and are briefly described below.

Table 6.1: Nine Flame Retardant Chemicals Evaluated Using Green Screen			
Chemical Name	CAS # ¹⁵⁴	Structure	Type of Flame Retardant
Decabromodiphenyl ether (decaBDE)	1163-19-5		Brominated additive (halogenated)
Aluminum trihydroxide	21645-51-2		Mineral-based additive (non-halogenated)
Ammonium polyphosphate	68333-79-9		Phosphorus-based additive (non-halogenated)
Ethylenediamine phosphate	14852-17-6		Phosphorus-based additive (non-halogenated)
Magnesium hydroxide	1309-42-8		Mineral-based additive (non-halogenated)
Magnesium stearate	577-04-0		Mineral-based additive (non-halogenated)

¹⁵⁴ CAS Registry Numbers are unique numbers given to chemicals by the [Chemical Abstracts Service](https://pubchem.ncbi.nlm.nih.gov/).

Melamine polyphosphate	218768-84-4	$\text{HO}-\left[\text{P}\begin{array}{c} \text{O} \\ \parallel \\ \text{O}^- \end{array}-\text{O}\right]_n\text{H}$ 	Nitrogen-based additive (non-halogenated)
Red phosphorus	7723-14-0	$\text{P}^{(0)}$	Mineral-based additive (non-halogenated)
Zinc borate	1332-07-6		Synergist in non-halogenated and halogenated systems

Aluminum trihydroxide is a solid, non-halogenated flame retardant. It is also used in the manufacturing of glass, ceramics, activated alumina, and mattress bedding. Aluminum trihydroxide is an additive mineral flame retardant, filler, and an additive for fume reduction. Because it is a relatively weak-acting flame retardant, it must be utilized in large quantities, which limits its application area. In addition, aluminum trihydroxide decomposes at 200°C, which further limits its application and it cannot be used in plastics with high processing temperatures.

Ammonium polyphosphate (APP) is a solid, ionic, non-volatile polymer used for flame retardation. APP is an intumescent coating, meaning it swells as a result of heat exposure and produces a carbonaceous foam which is a poor conductor of heat, thus retarding heat transfer. APP has excellent flame retardant characteristics in cellulose-containing materials such as paper and wood products but is also classified for use on steel and plastic surfaces as well as adhesives and sealants. Additionally, APP is also used as a fertilizer. Because no relevant toxicity data were identified for the possible reproductive, developmental, acute and systemic toxicity of APP, sodium tripolyphosphate, was selected as a chemical surrogate due to its structural similarity, use as a flame retardant, and use as a surrogate in several previous reports.

Ethylenediamine phosphate is a non-halogenated flame retardant salt composed of a mixture of ethylenediamine and phosphate. Because no relevant toxicity data were

identified to assess possible skin/eye corrosion, skin/respiratory sensitization, mutagenicity, reproductive, developmental, acute, or systemic toxicity of ethylenediamine phosphate, the individual components, ethylenediamine and phosphate, were evaluated to address data gaps.

Magnesium hydroxide is commonly used as an antacid and is the active ingredient in the laxative milk of magnesia. Additionally, it is used as a residual fuel-oil additive, an alkali drying agent in food, a color-retention agent, and is an ingredient in teeth. Magnesium hydroxide is used as a flame retardant in commercial furniture applications in the United States in addition to commercial and residential furniture in the United Kingdom. The stability of magnesium hydroxide at temperatures above 300°C allows it to be incorporated into several polymers.

Magnesium stearate is commonly used as a binder in drug tablets and as an emulsifier in cosmetics. Magnesium stearate is Generally Recognized as Safe (GRAS)¹⁵⁵ for addition to food; therefore the chemical is not thought to pose serious health hazards to humans at low levels of exposure. Environmentally however, the chemical has a tendency to persist.

Melamine phosphates are salts of melamine and phosphoric acid. These salts have good properties of thermal stability and are commonly used as flame retardants. Melamine and its derivatives (cyanurate and phosphates) are currently used in flexible polyurethane foams, polyamides and thermoplastic polyurethanes, and flame retardant (intumescent) coatings. There were not extensive data for melamine polyphosphate. In cases of data gaps, data for melamine phosphate, and the ions for melamine and phosphate were considered.

Red phosphorus is one of three allotropic forms¹⁵⁶ of the element phosphorus. Black phosphorus is the least reactive allotrope and is produced by heating white phosphorus under high pressure (about 12,000 atmospheres). White phosphorus, sometimes called

¹⁵⁵ Food and Drug Administration (FDA) guidance on GRAS states: “‘GRAS’ is an acronym for the phrase **Generally Recognized As Safe**. Under sections 201(s) and 409 of the Federal Food, Drug, and Cosmetic Act ..., any substance that is intentionally added to food is a food additive, that is subject to premarket review and approval by FDA, unless the substance is generally recognized, among qualified experts, as having been adequately shown to be safe under the conditions of its intended use, or unless the use of the substance is otherwise excluded from the definition of a food additive.” <http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodIngredientsandPackaging/ucm061846.htm#Q1>.

¹⁵⁶ Phosphorus is among the chemical elements that exhibit “allotropy,” the property to exist in two or more different forms or “allotropes.” See *Wikipedia*, <http://en.wikipedia.org/wiki/Allotropy>.

yellow phosphorus, is the least stable, most reactive, most volatile, and most toxic of the three isotopes. Exposure to sunlight can cause white phosphorus to convert into amorphous red phosphorus. Further heating results in the amorphous red phosphorus becoming crystalline. Red phosphorus can be converted back to white phosphorus by heating it to 260°C.

Zinc borate is used as a flame retardant in conjunction with other chemicals, including antimony trioxide, magnesium hydroxide, alumina trihydrate, and some brominated flame retardants. There are limited studies in the literature characterizing the toxicity of zinc borate. However, multiple toxicity studies have been performed on other inorganic borates. Additionally, zinc borate readily breaks down in the stomach to zinc oxide (ZnO) and boric acid (H₃BO₃). Therefore, in the absence of data for zinc borate, data for zinc oxide and boric acid have been substituted.

Results

Table 6.3 summarizes the hazard ratings and provides the Green Screen Benchmark scores for the nine flame retardants. These ranged from 1 to 4: one chemical received a Green Screen score of 4 (“Prefer- Safer Chemical”); six chemicals received Green Screen scores of 2 (“Use but Search for Safer Substitutes”); and two chemicals, including decaBDE, received Green Screen scores of 1 (“Avoid-Chemical of High Concern”).

Only ammonium polyphosphate received a Green Screen score of 4 (“Safer Chemical”) because no concerns regarding human health effects, aquatic toxicity, or environmental effects were identified.

Six chemicals received Green Screen (GS) scores of 2 (“Use but Search for Safer Substitutes”):

- **Aluminum trihydroxide:** GS 2 score due to its moderate neurotoxicity, irritation, repeat dose toxicity and very High persistence.
- **Ethylenediamine phosphate:** GS 2 score due to its moderate mutagenicity, reproductive/developmental toxicity, acute toxicity and repeat dose toxicity. Ethylenediamine phosphate also received High hazard rankings due to potential irritation, sensitization, and chronic aquatic toxicity.
- **Magnesium hydroxide:** GS 2 score due to its moderate irritation and repeat dose toxicity, as well as its very high persistence.
- **Magnesium stearate:** GS 2 score due to its high persistence and moderate irritation/corrosion and systemic toxicity.

- **Melamine polyphosphate:** GS 2 score due to its moderate carcinogenicity, mutagenicity, and persistence, in addition to its high repeat dose toxicity.
- **Zinc borate:** GS 2 score based on its very high persistence and moderate reproductive and developmental toxicity as well as acute aquatic toxicity.

In addition to the Green Screen score of 1 assigned to decaBDE, red phosphorus was also assigned a Green Screen score of 1 (“Avoid-Chemical of High Concern”).

- **Red phosphorus:** GS 1 score for hazard ratings of high for neurotoxicity, acute toxicity, irritation, and repeat dose toxicity. In addition, red phosphorus received hazard ratings of high for explosivity and flammability. Based on the high scores for neurotoxicity, acute toxicity, irritation, and repeat dose toxicity, and red phosphorus’s conversion into the more toxic white phosphorus via exposure to sun light, red phosphorus was assigned a benchmark score of 1.
- **DecaBDE:** GS 1 score based on its special risk due to its affinity to persist and bioaccumulate in the environment where it can enter the food chain and eventually pose a toxic risk to humans. This is significant because chemicals with moderate to high human toxicity that persist in the environment are able to exert their toxic effects over a long period of time.

Table 6.2: Green Screen (Version 1.0) Levels of Concern for Nine Flame Retardants

Screening Level Toxicology Hazard Summary

Chemical	CAS #	Human Health Effects									Aquatic Toxicity		Fate		Physical		GS Benchmark Score (Chemical)
		Carcinogenicity	Mutagenicity	Reproductive/ Developmental	Endocrine Disruption	Neurotoxicity	Acute Toxicity	Skin/Eye Corrosion/Irritation	Dermal/Respiratory Sensitization	Systemic Toxicity/ Repeated Dose	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Explosivity	Flammability	
Decabromodiphenyl Ether	1163-19-5	M	L	M	M	M	L	M	L	M	H	H	vH	M	nd	L	1
Aluminum Trihydroxide	21645-51-2	L	L	L	nd	M	L	M	L	M	L	M	vH	L	L	L	2
Ammonium Polyphosphate	68333-79-9	L	L	L	nd	nd	L	L	L	L	L	L	L	L	L	L	4
Ethylenediamine Phosphate	14852-17-6	L	M	M	nd	nd	M	H	H	M	L	H	M	L	L	L	2
Magnesium Hydroxide	1309-42-8	L	L	L	nd	L	L	M	L	M	L	L	vH	L	L	L	2
Magnesium Stearate	557-04-0	L	L	L	nd	nd	L	M	L	M	L	M	H	L	M	H	2
Melamine Polyphosphate	218768-84-4	M	M	L	nd	nd	L	L	L	H	L	L	M	L	L	L	2
Red Phosphorus	7723-14-0	L	L	L	nd	H	H	H	L	H	L	M	M	L	H	H	1
Zinc Borate	1332-07-6	L	L	M	M	nd	L	M	L	M	H	nd	nd	L	L	L	2
nd=not determined/unknown L=Low Hazard M=Moderate Hazard H=High Hazard vH=very High Hazard-Endpoints in colored text (L, M, and H) were assigned based on experimental data. Endpoints in black italics (L, M, and H) were assigned using estimated values and professional judgment (Structure Activity Relationships)																	

Comparative Hazard Assessment

As presented in Table 3, Green Screen scores assigned for the nine flame retardants demonstrate that other than red phosphorus, several less hazardous alternatives for decaBDE exist. Among the eight alternative flame retardants screened, ammonium polyphosphate (APP) has been shown to have acceptable health effects and environmental toxicity profiles, and is not likely to persist in the environment. This favorable profile resulted in APP receiving a Green Screen score of 4, which is the most favorable Green Screen rating among all eight alternative flame retardants screened.

Six of the alternative flame retardants received Green Screen scores of 2, indicating that they are less hazardous than decaBDE. These chemicals are: aluminum trihydroxide, ethylenediamine phosphate, magnesium hydroxide, magnesium stearate, melamine polyphosphate, and zinc borate. Two of these chemicals, aluminum trihydroxide and magnesium hydroxide, were assigned final Benchmark scores of 2 based on very high persistence. Both chemicals are fully oxidized inorganic materials, and are therefore not expected to biodegrade, oxidize in air, or undergo hydrolysis or pyrolysis under normal environmental conditions. In fact, no degradation processes under typical environmental conditions were identified (U.S. EPA 2008). Under the CPA's Version 1.0 criteria, "recalcitrant" chemicals (chemicals that are resistant to degradation), although not inherently toxic, are assigned a Benchmark score of 2. Both of these chemicals were assigned a low mark for bioaccumulation, making them less of a risk to the environment because they are not expected to accumulate in aquatic and terrestrial organisms.

Ethylenediamine phosphate, magnesium stearate, melamine polyphosphate, and zinc borate all received final Benchmark scores of 2 after receiving scores of high for one or more toxicity endpoints. A score of high for any endpoint will result in a chemical receiving a final Benchmark score of 2.

Conclusion

This report evaluates the health and environmental hazards of nine different flame retardants. Each chemical was evaluated against the health and environmental fate and toxicity criteria of Clean Production Action's Green Screen, Version 1.0.¹⁵⁷ For each flame retardant, endpoints relating to human health effects, aquatic toxicity, and environmental effects were evaluated,

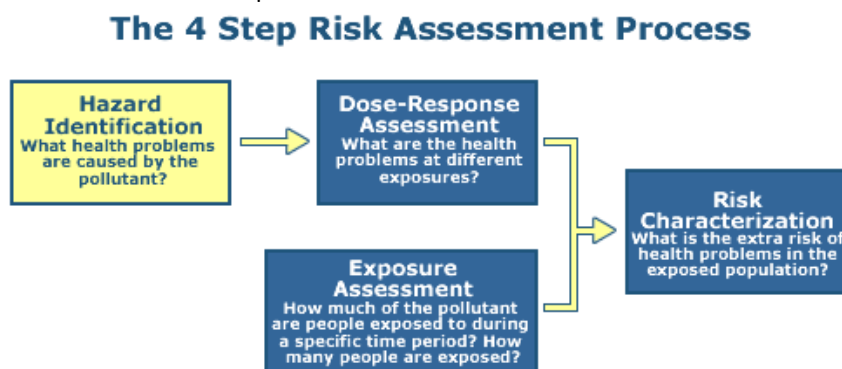
¹⁵⁷ Clean Production Action (CPA). 2009. The Green Screen for Safer Chemicals, Version 1. September, 2009.

and each endpoint was given a score of Low hazard (L), Moderate hazard (M), High hazard (H), or very High hazard (vH).

The Green Screen is a hazard-based screening tool and its predicted results should be considered as such. Hazard assessments are components of a risk assessment, but do not in themselves constitute a risk assessment.¹⁵⁸ In most industries, hazards cannot be abolished in the sense that they are completely removed. The Green Screen is a valuable tool in that it can be used for both informed substitution and continuous improvement of formulated materials through use of less hazardous ingredients.

Green Screen scores assigned for the nine flame retardants demonstrated that other than red phosphorus, several alternatives for decaBDE exist. Namely, ammonium polyphosphate has been shown to have low human and environmental toxicity and is unlikely to persist in the environment, and received a Green Screen score of 4 (“Safer Chemical”), while six chemicals received Green Screen scores of 2 (“Use but Search for Safer Substitutes”).

¹⁵⁸ National Research Council Committee to Review the OMB Risk Assessment Bulletin (NRC), 2007. Scientific Review of the Proposed Risk Assessment Bulletin from the Office of Management and Budget. The National Academies Press. The following U.S. EPA graphic shows the relationship between the intrinsic hazard of a pollutant and an assessment of the risk it poses:



http://www.epa.gov/risk_assessment/hazardous-identification.htm.

Chapter VII: Comparison of Pallet Attributes

Based on the results of the Green Screen evaluations, there are a number of flame retardants with safer ratings than decaBDE that could potentially be used in plastic pallets. As the information in previous chapters indicates, however, there are numerous challenges to taking the step from a promising flame retardant to a pallet which both passes fire safety tests and meets the performance needs for a pallet. As specified by DEP, this chapter compares available information on the performance attributes of the following pallets:

- A plastic 48 x 40 shipping pallets containing decaBDE.
- Two plastic 48 x 40 shipping pallets containing non-halogenated flame retardants that have received scores of 2 (use, but search for safer substitutes) in Green Screen assessments.
- Two wood 48 x 40 shipping pallets used for shipping and storing products in the same or similar market sectors (e.g., groceries or other fast turnover consumer goods).

DEP also specified that, if there are no non-halogenated flame retardant 48 x 40 plastic pallets potentially available for use in the same markets currently served by the flame retardant 48 x 40 plastic pallet with decaBDE, then the report should review available information comparing small test specimens of polymers made with decaBDE with similar test specimens made with non-halogenated flame retardants. We have seen that there are now two plastic 48 x 40 shipping pallets using non-halogenated flame retardants – one using a metal hydrate-based flame retardant and the other a proprietary phosphorus-based flame retardant. Therefore this further analysis comparing small test specimens of polymers made with unproven flame retardants is not necessary.

In addition to the pallets above, at least one company (Orbis) is developing a new 48 x 40 pallet with a proprietary, non-halogenated flame retardant, and currently preparing for testing under either UL 2335 or FM 4996. It will be important to track this development over the coming months and, should it be listed under these standards, to screen the flame retardant for potential hazards and review the adequacy of the pallet's performance attributes for use in the open-pool market. Information on this pallet is currently unavailable, so it cannot be included in the comparison for the purposes of this report.

Comparisons of Pallets

Two companies currently manufacture or use plastic pallets with non-halogenated flame retardants that have passed either the UL 2335 or FM 4996 tests to demonstrate fire risk equivalent to or less than that of wood:

- Rehrig Pacific Company, with a UL 2335-certified pallet using a magnesium hydroxide-based flame retardant which includes ATH and zinc borate.
- CHEP (no information on the manufacturer), with a UL 2335-certified and FM 4996-approved pallet using a proprietary phosphorus-based flame retardant that has passed a Green Screen assessment with a '2' .

In addition to comparing, to the extent information is available, the attributes of these two pallets to that of the iGPS/Schoeller Arca Group pallet with decaBDE flame retardant, the comparison will include wood pallets used in open pooling, including both the CHEP wood pallet – which is the most widely used pallet in the open pooling market – and the PECO pallet.

The scope of work for this project requires a comparison of these pallets with respect to the following attributes:¹⁵⁹

- *Availability in 48-inch x 40-inch dimensions;*
- *Weight;*
- *Load capacity as measured in accordance with the testing methodologies of ISO 8611-1 Pallets for materials handling — Flat pallets and ASTM D 1185 - 98a (reapproved 2009) Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping;*
- *Expected life in years assuming 5 trips per year and forklift transport;*
- *Susceptibility to breakage and ease of repair;*
- *Weather and moisture resistance;*
- *Recyclability;*
- *Ability to meet the Grocery Industry Pallet Performance Specifications as set forth on page 11 of the Recommendations on the Grocery Industry Pallet System, Cleveland Consulting Associates, 1992;*
- *Ability to accommodate radio frequency identification; and*
- *Cost to users.*

There is some duplication in these attributes, since the GMA specifications¹⁶⁰ cover most of the specifically identified attributes in this list – though not with the specificity of the ISO and ASTM standards. In Table 7.1 below, the attributes of the CHEP flame retardant plastic pallet, the CHEP and PECO wood pallets, and the Rehrig Pacific flame retardant plastic pallet are compared

¹⁵⁹ Specifications of Work to Be Performed, Task 11.

¹⁶⁰ For the complete text of the GMA Pallet Performance specifications, see Appendix II

with the attributes of the iGPS/Schoeller Arca Group plastic pallet made with a decaBDE flame retardant. Information on the Rehrig Pacific and PECO pallets comes from available product information on their company websites.¹⁶¹

The left column lists the attributes from the above list, combining the GMA specifications with the other attributes where appropriate, as almost all of the attributes are found in some form on the GMA list.

Table 7.1: Comparison of Attributes of Plastic Pallets with DecaBDE, Plastic Pallets with Safer Flame Retardants, & Wood Pallets

Pallets/Companies ¹⁶²	iGPS HDPE w/ decaBDE [Information provided by iGPS unless otherwise noted]	CHEP HDPE & PP w/ Proprietary Phosphate [Information provided by CHP unless otherwise noted]	CHEP Wood (no flame retardant) [Information provided by CHP unless otherwise noted]	Rehrig Pacific Co. PP w/ Magnesium Hydroxide, ATH & zinc borate ¹⁶³	PECO Wood (no flame retardant) ¹⁶⁴
Pallet attributes¹⁶⁵					
Availability: 40 " x 48" [GMA #1 ¹⁶⁶]	iGPS pallet is 40" x 48"	Yes	Yes	Yes	Yes
4-way entry [GMA #2]	Yes	Yes	Yes	Yes	Yes
12" pallet jack openings & 3&3/4" height clearance under load [GMA #3] [ISO 8611 8.5 Compression deflection test] [ASTM 1185 (98a) 8.5 Deflection Tests]	Yes. 12.5" x 3.5" (40" side) and 14.7 x 3.5" (48" side) with each center block width less than 6"	Yes. Exceeds corresponding ISO 8611 performance standards ¹⁶⁷	Yes. Exceeds corresponding ISO 8611 performance standards	Information not available	Information not available

¹⁶¹The information on the iGPS and CHP pallets was provided to Pure Strategies by the companies, except where other source noted in footnote. The information on the Rehrig Pacific UL-classified pallet comes from the company's website. For information on the Rehrig Pacific pallet:

<http://www.rehrigpacific.com/docs/PAL%20008%20060515%2023029%2040x48%20FR%20Rackable.pdf>
<http://www.pdfdownload.org/pdf2html/pdf2html.php?url=http%3A%2F%2Fwww.rehrigpacific.com%2Fdocs%2FBulletin%20PAL%20102%200906%20All%20Pallets.pdf&images=yes> .
http://pecopallet.com/our_pallets/pallet_specifications.php.

¹⁶² The ISO and ASTM tests listed come from: ISO 8611 (2004 & 2005) "Pallets for Materials Handling – Flat Pallets;" and ASTM D1185 – 98a (Reapproved 2009), "Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping."

¹⁶³ <http://www.rehrigpacific.com/docs/PAL%20008%20060515%2023029%2040x48%20FR%20Rackable.pdf>

¹⁶⁴ http://pecopallet.com/our_pallets/pallet_specifications.php.

¹⁶⁵ Sources of the attributes (GMA, ASTM and/or ISO) are also indicated in this column.

¹⁶⁶ GMA Grocery Industry Pallet Performance Specifications

¹⁶⁷ With respect to GMA #3, CHP states that "ISO 8611 performance standards ... are more rigorous than GMA."

Pallets/Companies¹⁶²	iGPS HDPE w/ decaBDE [Information provided by iGPS unless otherwise noted]	CHEP HDPE & PP w/ Proprietary Phosphate [Information provided by CHP unless otherwise noted]	CHEP Wood (no flame retardant) [Information provided by CHP unless otherwise noted]	Rehrig Pacific Co. PP w/ Magnesium Hydroxide, ATH & zinc borate¹⁶³	PECO Wood (no flame retardant)¹⁶⁴
>85% top surface coverage [GMA #4]	Yes. (97%)	No specific % provided. CHP says pallet offers better product packaging support than its wood pallets due to honeycomb design	Up to 87% top deck coverage [from website]. ¹⁶⁸ Utilizes varying top deck designs. ¹⁶⁹	Information not available	Information not available
>60% bottom surface coverage [GMA#5]	No. (57%)	No specific % provided. ¹⁷⁰	55% coverage [from website]. ¹⁷¹	No specific % on website. Reports that pallet has a “large bottom deck surface.”	Information not available
Bottom edges chamfered ¹⁷² to ¼” [GMA #6]	1/8”	Bottom edges are chamfered	No. ¹⁷³	Bottom edges are chamfered	Information not available
Height not >6” [GMA #7]	Yes. (5.62”)	Yes.	Yes.	Yes. (6”)	Yes. (5.56”)
Compatible with pallet conveyors [GMA #9]	Yes	Yes	Yes	Information not available	Information not available
No protruding fasteners [GMA #10]	None used	No	No	None	Information not available
Rack Load capacity, 2800 lbs, and edge rackable in both 40” & 48” dimensions (maximum allowable dimension change (deformation) under weight load) [GMA #15 & 8 ; ASTM 1185 98a 8.4; or ISO 8611-1 8.1.3.1 &2]	Yes. (2,800 lbs)	Yes. (Rated at 2,800 pounds) ¹⁷⁴	Yes. (Rated at 2,800 pounds)	No. (2,000 lbs.)	Yes. (2,800 lbs.)
Stack load capacity, lbs [maximum allowable dimension change (deformation) under 30,000 lbs] [GMA #15, ISO 8611 8.6 or ASTM 1185 8.5]	Yes. (30,000 lbs.)	Yes. (30,000 pounds / dynamic load 5,000 pounds)	Yes. (30,000 pounds / dynamic load 5,000 pounds)	Yes. (30,000 lbs.)	Information not available
Expected life (assuming 5 trips/ year & forklift transport) [GMA #19]	15 years	12 years. ¹⁷⁵	6 years. ¹⁷⁶	Information not available	Information not available

¹⁶⁸ CHP specifications for B4840A. <http://www.chep.com/getattachment/95c39cdb-2cc1-485c-b1c3-3f747c5e1c08/48x40-Wood-Pallet-%281%29-%281%29.aspx>

¹⁶⁹ CHP responded that “85% top deck coverage is not a current industry standard.”

¹⁷⁰ CHP responded that 60% bottom surface coverage “not a current industry standard.” CHP also noted that both pallets utilize “a perimeter and crucifix design for greater weight distribution than stringer pallets.”

¹⁷¹ Specifications for B4840A

¹⁷² This is an engineering term relating to beveled edges.

¹⁷³ CHP says that chamfered edges for a wood pallet would “lead to excessive pallet damage.”

¹⁷⁴ CHP response for both pallets states that, for rack load, the “company’s designed-in safety factor is more than 2x.” For edge rackability in both directions, both pallets “include a significant safety factor above rated loads.”

¹⁷⁵ CHP Life Cycle Analysis (peer reviewed) utilized 60 trips.

Pallets/Companies¹⁶²	iGPS HDPE w/ decaBDE [Information provided by iGPS unless otherwise noted]	CHEP HDPE & PP w/ Proprietary Phosphate [Information provided by CHEP unless otherwise noted]	CHEP Wood (no flame retardant) [Information provided by CHEP unless otherwise noted]	Rehrig Pacific Co. PP w/ Magnesium Hydroxide, ATH & zinc borate¹⁶³	PECO Wood (no flame retardant)¹⁶⁴
Susceptibility to breakage Is determined by pallet performance in ISO 8611 9.1:9.2.2, 9.2.3, 9.2.4 or ASTM 1185 98a 9.3,9.4, 9.5	Low damage rate	Meets the ISO 8611 drop tests. ¹⁷⁷	Meets the ISO 8611 drop tests.	Information not available	Information not available
Weather resistant [GMA #17]	UV, moisture, temperature resistant.	FM conducts accelerated weathering tests and pallet passed 4996 standard	FM conducts accelerated weathering tests and CHEP passed 4996 standard	Information not available	Information not available
Moisture resistant [GMA #18]	Made with non-absorbing HDPE (intrinsically hydrophobic)	Yes. Has an open design allowing drainage from blocks.	Standard for industry	Yes	Information not available
Repairs economically feasible [GMA #16]	N/A ¹⁷⁸	Yes	Yes	Information not available	Information not available
Recyclability [GMA #13]	Yes. 100% recyclable	Yes	Yes	Information not available	Information not available
Won't contaminate product [GMA #11]	Non-absorbing (hydrophobic), cleanable/washable, NSF International certified (see notes); not designed for direct food contact.	CHEP observes that the US Food, Drug, and Cosmetic Act does not allow for non-food items (pallets, truck floors, forklifts, etc.) to come into direct contact with food unless they are specifically designed for this purpose. Neither CHEP pallet is designed for such a purpose.		Information not available	ISPM 15 certified
Weight [GMA #14 "Desired weight < 50 lbs."]	Less than 50 lbs. (Approximately 48.5 lbs.)	62 pounds. ¹⁷⁹	Approximately 65 lbs.	49.5 lbs.	Information not available
Approved under FM 4996 or UL 2335 [GMA #12]	FM 4996 Approved and UL 2335 Classified	FM 4996 Approved and UL 2335 Classified	Most all wood. Those with composite block FM 4996 approved	UL-2335 classified	Wood. No listing required.
Accommodates radio frequency identification (RFID)	4 RFID chips in each pallet	Yes; all include RFID	Yes, though most do not contain RFID tags		
Cost to User	Rental Pooled Pallet, Comparable with Wood Pallet Rental Pool	Industry standard range	Industry standard range		

¹⁷⁶ CHEP Life Cycle Analysis (peer reviewed) utilized 30.3 trips

¹⁷⁷ CHEP's response for both pallets additionally states: "Designed to exceed all industry standard testing, as well as additional, and more rigorous CHEP specific testing."

¹⁷⁸ N/A = not applicable

¹⁷⁹ CHEP response additionally states: "This plastic pallet has a significant amount of steel in the top deck. This additional steel provides significant improvements in deflection."

Using the information from this table, we can summarize the similarities and differences between these pallets, although with information available only from the websites for Rehrig Pacific Company and PECO, there are limits on the comparisons that can be made.

- *Common attributes of all pallets:* There are five areas where all five of the pallets appear to meet industry standards or expectations, even though there may be specific differences: 40" x 48", height, 4-way entry, stack load capacity and fire retardance.
 - With respect to fire retardance, two of the pallets are listed (iGPS, CHEP plastic) as having fire hazards equivalent to or less than wood under both UL 2335 and FM 4996; two others have one of these listings (Rehrig Pacific Company – UL 2335; CHEP wood pallet with composite blocks – FM 4996); while the PECO wood pallet and the CHEP all-wood pallet require no listing.
 - It seems likely that the costs to users of all the open-pooled pallets are in an "industry standard range." As Rehrig Pacific Company sells pallets directly to end users, there is no meaningful way of comparing their prices to the per-use rental rates of PECO, iGPS and CHEP.
 - At least four of the pallets meet the specification of no protruding fasteners; for the fifth (PECO), information on the website didn't address this specification.
- *Rack load capacity:* Four of the five pallets (iGPS, CHEP [both], PECO) meet the rack load capacity of 2,800 pounds, and can be racked in both directions. Rack load capacity of 2,800 pounds is considered an industry requirement for the various products shipped and stored on open pool pallets. So the 2,000 pound rack load capacity of the Rehrig Pacific pallet company, although that can meet needs in a wide range of closed or captive uses,¹⁸⁰ is not sufficient for open pool use.
- *Additional common attributes of the plastic pallets:* All three plastic pallets are moisture and weather resistant. Wood is generally more susceptible to the effects of moisture than plastic. CHEP states that its wood pallet is "standard for the industry."
- *Additional common attributes of the iGPS pallet and both CHEP pallets:* In four additional areas of comparison (susceptibility to breakage, feasibility of cost-effective repairs, recyclability, and height clearance of pallet openings under load), CHEP and iGPS report that their pallets meet relevant GMA, ASTM or ISO standards. While no specific available information addresses these issues for Rehrig Pacific Company or PECO, each may meet some or all of these specifications. For example, refurbishing and repair of wood pallets, with extensive reuse and recycling of pallet components, has dramatically

¹⁸⁰ GMA's "Recommendations on the Grocery Industry Pallet System" (1992) notes that "approximately 30% of the unit loads weigh less than 1,000 pounds, and 66% of unit loads weigh under 2,000 pounds," GMA, "Recommendations on the Grocery Industry Pallet System," 1992, p. 9.

increased as an industry practice since the late 1990s,¹⁸¹ and it seems likely that PECO recycles its pallets.

- *Top & bottom surface coverage:* The iGPS pallet meets the GMA specification for top surface coverage, though bottom surface coverage is 3% less than the GMA specification. CHEP states these are not industry standards, and refers to alternative design parameters to achieve the purpose of these standards. Data on the CHEP website states that the wood pallet has “up to 87% top deck and 55% bottom deck coverage.”¹⁸² Top deck coverage of 87% would meet the GMA specification; the bottom deck coverage is 5% less coverage than in the GMA specification. Information on the Rehrig Pacific Company website states that the pallet has a large bottom deck surface.
- *Expected Life:* Both CHEP and iGPS estimate substantial durability for their plastic pallets. Using the data provided by the companies, and given the assumption of five trips/year, the estimated life for the iGPS pallet is 15 years, for the CHEP plastic pallet 12 years. For its wood pallet, CHEP estimates 6 years. [No specific estimates were available on the websites for Rehrig Pacific Company or PECO].
- *Weight:* The iGPS and Rehrig Pacific Company pallets both weigh less than 50 pounds, while both wood pallets and the CHEP plastic pallet exceed 50 pounds. (At 62 pounds, the CHEP plastic pallet exceeds the GMA desired weight by 24%).
- *Contamination of product:* The exact wording of the GMA’s specification is that the pallet “must be made of material that does not contaminate the product it carries.”
 - *DecaBDE flame retardant pallet:* Beyond the general concern for the potential for decaBDE to get into the environment, there is a specific question about contamination of products. To partially address this issue, iGPS contracted with Environ to conduct a study of the transfer of decaBDE from pallets to products while sitting unmoved in storage for 3 weeks. Environ found no observed transfer of decaBDE from polymer pallet surfaces onto product containers.¹⁸³ In addition, as noted in Table 7.1, the iGPS pallet has received NSF/ANSI Standard 2 certification under NSF International’s Food Equipment Certification Program, which certifies that the design of the pallet will prevent harborage of pests or accumulation of dirt, and permits easy maintenance and cleaning. The standard is for indirect food contact and does not include toxicological testing. With

¹⁸¹ Robert J. Bush (Virginia Tech) and Philip A. Araman (USDA Forest Service), “Updated Pallet and Container Industry Production and Recycling Research” SRS 04-CA-11330142-205, October 11, 2008.

¹⁸² <http://www.chep.com/getattachment/95c39cdb-2cc1-485c-b1c3-3f747c5e1c08/48x40-Wood-Pallet-%281%29-%281%29.aspx>

¹⁸³ Environ International Corporation, “Consumer Products Stored on Polymer Pallets Containing Decabromodiphenyloxide: Evaluation of Potential Surface-to-Surface Transfer,” prepared for iGPS Company LLC, November 2009.

respect to direct food contact through a practice such as hydrocooling, iGPS policy is that “we do not authorize use of our pallets for this purpose.”¹⁸⁴

- *Other pallets:* Wood pallets often raise concerns because of their potential for absorbing spills, harboring insects, etc. These are the types of challenges plastic pallets can help to solve, as evidenced by the NSF certification of the iGPS pallet. For international shipping, wood pallets generally require heat treatment (the alternative of chemical treatment has ended). CHEP notes that the FDA prohibits direct food contact with pallets.
- Accommodation of RFID: Both the iGPS and CHEP plastic pallet are made with RFID chips. The CHEP wood pallet can accommodate RFID, though most do not. RFID can provide real benefits in overall logistics efficiency. At present, system-wide use of RFID is an economic benefit for customers unique to iGPS. CHEP is developing the capacity with some of its pallets, but does not yet have a comprehensive system for all its users.

Of these four alternatives to a decaBDE flame retardant pallet, two (wood or modified wood) are currently in use as open pool pallets, while a third (the new CHEP plastic pallet) will likely be in use for open pool shipping shortly. The Rehrig Pacific Company pallet lacks sufficient rack-load strength to be an open-pool shipping pallet. The iGPS pallet has attributes that none of the alternative pallets match, particularly its light weight. This can reduce shipping costs and reduce ergonomic risks for workers in warehouses, distribution centers or stores in settings where still lighter plastic nestable pallets are not used when pallets require manual handling. In addition, the iGPS RFID system provides a substantial logistics benefit to customers, as well as cost savings in the management of pallets. But on most measures, the CHEP plastic pallet, and in many cases the two wood pallets, matches the attributes of the iGPS pallet.

¹⁸⁴ iGPS, “iGPS All-Plastic Pallet Receives NSF Food Equipment Certification,” July 6, 2010. Personal communication from Mark Sanford, Business Development Manager, Food Equipment Group, NSF International, December 3, 2010. Personal communication from Bruce Torrey, iGPS, via email, December 3, 2010.

Chapter VIII: DecaBDE Plastic Pallets & Functionally Equivalent Alternatives

On the basis of the comparisons in Chapter 7, Maine DEP requires this report to “identify which, if any, of the pallet alternatives are functionally equivalent to plastic pallets containing decaBDE.”¹⁸⁵ DEP defines two alternative criteria for a finding that there is an available, “functionally equivalent” pallet.

“For the purpose of the study, a pallet will be considered functionally equivalent if:

- The pallet meets the Grocery Industry Pallet Performance Specifications as set forth on page 11 of the Recommendations on the Grocery Industry Pallet System, Cleveland Consulting Associates, 1992 or is capable of being manufactured to meet those standards; or*
- The pallet currently is used by the grocery industry or other market sectors to ship the same types of good shipped on pallets containing decaBDE.”¹⁸⁶*

This chapter will consider each criterion in turn. As specified by DEP, this review will consider both available plastic and wood pallets.

Criterion #1: Pallet Meets GMA “Grocery Industry Pallet Performance Specifications”

Under this criterion, there is no functionally equivalent alternative pallet to the plastic pallet containing decaBDE.

None of the current potential alternative pallets, neither wood pallets nor the plastic pallet, meets all of the GMA specifications. Using the information related specifically to the GMA specifications from Table 7.1, the following are the specifications that one or more of the pallets do not meet:¹⁸⁷

- “Desired weight” limit of less than 50 pounds (GMA #14):* The wood pallets currently in use in the open pool pallet leasing market both exceed 50 pounds; the CHEP wood pallet is approximately 65 pounds. The new CHEP plastic pallet is 62 pounds. The Rehrig Pacific Company pallet is only 49.5 lbs. The iGPS decaBDE flame retardant pallet, also meets this specification at 48.5 pounds.
- Top and bottom deck surface coverage of 85% (top surface) and 60% (bottom coverage) (GMA #s 4&5):* CHEP did not provide data for this specification, but stated that neither

¹⁸⁵ Specifications of Work to Be Performed, Task 12 (as amended 10-13-10)

¹⁸⁶ Criteria in Task 12 of DEP’s “Specifications of Work to Be Performed” (as amended 10-13-10)

¹⁸⁷ As noted in the preceding chapter, we have limited data from PECO and Rehrig Pacific Company.

was an industry standard. In the absence of any data provided by the company, we conclude that CHEP wood and plastic pallets may not achieve these specifications (although, as noted in Table 7.1, at least some CHEP wood pallets may achieve 85% top deck surface coverage). The iGPS pallet exceeds the specification for the top surface (97%), and falls 5% short of the specification for the bottom surface (57%).

- *Rack load capacity of 2,800 pounds (GMA #15)*: The Rehrig Pacific Company plastic pallet (2,000 pounds) falls short of this goal for rackable strength. Both wood pallets and the CHEP plastic pallet meet or exceed this standard.
- *Must meet or exceed current pallet resistance to fire (GMA #12)*: Since the requirements for resistance to fire are based on equivalence to fire hazards of wood, and FM 4996 and UL 2335 test for equivalence to wood fire hazards, all of these pallets meet this requirement. The CHEP and iGPS plastic pallets have both UL 2335 and FM 4996 listings; the Rehrig Pacific Company pallet has a UL 2335 listing; for those CHEP wood pallets (less than 20%) that have composite blocks with plastic, CHEP has an FM 4996 listing; and the PECO and CHEP all-wood pallets (no composite) require no listing. As discussed earlier in this report, some industry players voiced disagreement with the use of the FM 4996 listing to meet the equivalence requirement. The only NFPA statement on the subject appears to be the unofficial commentary that refers to both standards as allowable at the discretion of local authorities.¹⁸⁸ We were unable to find an authoritative NFPA statement rejecting the applicability of FM 4996 listings.
- *Bottom edges chamfered to ¼" (GMA #6)*: The wood pallets are not chamfered, but the three plastic pallets are.

Table 8.3 summarizes the extent to which various pallets meet the GMA specifications.

Table 8.3: GMA Specification Comparison

Pallet	Weight (lb)	Bottom Surface Coverage	Top Surface Coverage	Rack Load	Fire Resistance	Edge Chamfer
iGPS	48.5	57%	97%	≥2,800	UL 2335 & FM 4996	Y
CHEP all wood	65	unknown	unknown	≥2,800	N/A	N
CHEP plastic	62	unknown	unknown	≥2,800	UL 2335 & FM 4996	Y
CHEP composite block	65	55%	unknown	≥2,800	FM 4996	N
PECO all wood	unknown	unknown	unknown	≥2,800	N/A	N
Rehrig Pacific plastic	49.5	unknown	unknown	2,000	UL 2335	Y

¹⁸⁸ NFPA, *Automatic Sprinkler Systems Handbook*, 11th Edition (2010), edited by James D. Lake, p.100.

Criterion #2: The pallet currently is used by the grocery industry or other market sectors to ship the same types of good shipped on pallets containing decaBDE.

Under this criterion, there is a functionally equivalent alternative to plastic pallets containing decaBDE.

Two pallets – the PECO wood pallet and the CHEP wood pallet – are used currently by the grocery industry or other market sectors to ship the same types of goods as are shipped on pallets containing decaBDE. A third pallet, the new CHEP plastic pallet, which just went into production at the beginning of December 2010, has been designed for use in that market. As it is not yet in the market, it is too early to say definitively whether or not it will be used by companies using open pool services to ship the same types of goods, CHEP’s market position as the largest open pool pallet company certainly makes this plausible.

Although none of the three pallets meets all of the GMA specifications, as discussed above, a large number of CHEP and PECO wood pallets are nonetheless used to ship the same types of goods as the iGPS pallet. According to the data summarized in Chapter I from Modern Materials Handling magazine (October 2010)¹⁸⁹ the three companies have approximately the following numbers of pallets in open pool use:

- CHEP – approximately 65 million pallets
- iGPS – approximately 10 million pallets
- PECO – approximately 5 million pallets.

While the use of iGPS pallets has grown rapidly, the wood pallets still dominate the open pool market. It is possible that there are particular subsectors currently served by iGPS pallets and not served by the CHEP and PECO wood pallets, but we found insufficient data to make such a determination.

What about the new CHEP pallet? It does not yet have any market share, having only gone into production at the beginning of December. As a plastic pallet with a non-halogenated flame retardant, it provides significant potential for developing another alternative to a decaBDE-based flame retardant pallet in a foreseeable future. CHEP’s strength in the open pool shipping market creates a substantial opportunity for accomplishing this. At the same time, CHEP has a substantial commitment to and investment in a market with wood pallets. Much will depend

¹⁸⁹ Modern Materials Handling Magazine, October 2010 issues: MMH magazine:
http://www.mmh.com/article/pallets_and_containers_the_plastic_pool_alternative/,
http://www.mmh.com/article/pallets_and_containers_a_chep_off_the_old_block/,
http://www.mmh.com/article/pallets_pallet_pooling_for_the_other_guys/.

on the degree to which CHEP aggressively commits itself to production, promotion and use of the new pallet as a strong element of its operations.

What about the fact that all three non-decaBDE pallets exceed, by a substantial amount, the GMA goal that a pallet should be less than 50 pounds? Whatever the undeniable benefits of a lighter pallet, approximately 70 million open-pool wood pallets (about 65 pounds) are currently in use. They provide an alternative to the plastic pallet with decaBDE.

Issues Related to Switching to Alternative Pallets

DEP requires that this report “identify any issues related to switching to ... alternatives if the sale of pallets made with decaBDE is banned.”¹⁹⁰

While there are substantial uncertainties about any impacts, since the design and schedule of a ban or phaseout could make a substantial difference, the following seem important possibilities to consider:

- Most important, it would eliminate a significant source of decaBDE that could affect human health and the environment.
- It could create an incentive, and a market opportunity, for pallet manufacturers and pallet management companies to invest in the development of alternative non-halogenated flame retardant pallets that also meet all pallet performance objectives. The combination of state actions and EPA’s voluntary agreement with the sources of decaBDE to phase out the flame retardant already seems to be influencing the market. As reported in Table 2.3, at least one other company is currently lining up to test a new pallet with a non-halogenated flame retardant under UL 2335 or FM 4996, although no information is publicly available on the particular flame retardant or the performance characteristics of the pallet.
- Beyond the company currently preparing for the UL and FM tests, the major companies leasing and manufacturing the decaBDE flame retardant plastic pallet, iGPS and Schoeller Arca respectively, are also working on an alternative to that pallet. We have no specific information on the current status of that development, since it is proprietary. Obviously a more competitive market benefits Maine businesses. iGPS and Schoeller Arca bring strong technical expertise and market experience to bear on the options for development and marketing of an alternative pallet, linked with the services iGPS’ RFID tracking system provides for their customers. It would be difficult to

¹⁹⁰ Task 12 of DEP’s “Specifications of Work to Be Performed” (as amended 10-13-10). This required task relates to the DEP’s obligation under PL 2009, c. 610, §11, to report to the Maine Legislature on issues related to the prohibition on replacing decaBDE with another brominated flame retardant or a chlorinated flame retardant. See 38 MRSA §1606(14)(B)(2).

anticipate how a ban or phaseout of decaBDE in shipping pallets would affect them, especially in the absence of knowing the particular design of such action by the state, and the current status of the effort by iGPS and Schoeller Arca to develop an alternative flame retardant pallet.

- While a large percentage of the market continues to operate with heavier pallets, the weight difference of over 20% between the iGPS pallet and any of the three alternative ones from CHEP or PECO represents, in the absence of a lower-weight replacement, a potential additional shipping expense for businesses and some increased air pollution from trucks.

None of these effects mitigates the need for removing a major source of decaBDE from the environment. But they are issues DEP might consider in determining the timing and design of any ban or phaseout.

Chapter IX: Findings

This chapter presents the findings of this report, and discusses how the structure of this assessment contributed to developing these findings. Finally, this chapter summarizes gaps in publicly available scientific or technical information about potential alternatives to decaBDE.

Report Findings

This section first presents the findings with respect to the central question this report addresses: Are there safer alternative management methods or replacement flame retardants that could eliminate any need for continued use of decabromodiphenyl ether as a flame retardant in plastic pallets? This section will then lay out the specific findings with respect to the tasks in the “Specifications of Work to Be Performed.”

Are There Safer Alternatives?

Finding 1: *While there are fire safety systems and management practices for warehouses and other shipping locations that can make the use of flame retardant plastic pallets unnecessary, these are not universally available, and do not provide a comprehensive short-term safer alternative to the use of plastic pallets with flame retardants.*

The NFPA’s fire protection standards for warehouses specify sprinkler systems and best management practices for commodities, packaging and pallets that present the most severe fire risks. Warehouses handling these commodities -- including many plastic products, cooking oils, and other highly flammable goods – must establish separate areas of the warehouse that meet the highest levels of protection. These levels would be sufficient for plastic pallets without flame retardants. Some new or modernized warehouses are built entirely with the highest protection levels, and can purchase and use plastic pallets without flame retardants.

But many warehouses, especially older warehouses, meet only minimum NFPA protection requirements. For these warehouses, general use of plastic pallets is only feasible if the pallets are flame retardant. The three open-pool leasing companies (iGPS, CHEP, PECO) moving rapid-turnover consumer products send pallets to warehouses all over the country, a significant proportion of which are not built to the highest possible standards. So the use of open-pool plastic pallets without flame retardants is not currently feasible as a safer alternative to the use of plastic pallets with decaBDE.

Finding 2: *‘Safer alternative’ non-halogenated flame retardants for plastic pallets are available, and at least one flame retardant plastic pallet meeting essential performance criteria for use in open pool leasing is now in production.*

This study has identified several non-halogenated alternative flame retardants that could potentially be used in plastic pallets and that would be safer for human health and the environment than continued use of decaBDE. One company, CHEP, has just begun production of a plastic pallet with such a safer alternative; the pallet has passed both of the tests (FM 4996 and UL 2335) that list plastic pallets as equivalent to or better than wood for flammability, and meets critical pallet performance specifications. At least one other company is currently scheduling a plastic pallet with an alternative non-halogenated flame retardant for testing under the FM or UL protocol. The emergence of plastic pallets with safer alternatives will allow a reduction in risks to human health and the environment from decaBDE without compromising fire safety.

Additional Findings

Plastic Pallet Manufacturers and Their Use of Flame Retardants (Tasks 1&2; Chapters 1&5)

Finding 3: *Of the twenty-one manufacturers of plastic pallets we identified, most make plastic pallets without flame retardants.*

Only six companies reported manufacturing plastic pallets with flame retardants. In most cases, even for these companies, it is only a small part of their market (e.g., Orbis estimates only 5% of plastic pallet sales with flame retardants).

Finding 4: *The majority of manufacturers of flame retardant plastic pallets use decaBDE as the flame retardant, but that may be changing.*

Four of the six manufacturers of flame retardant plastic pallets currently use decaBDE as the flame retardant. However two of these companies have plastic pallets with non-halogenated flame retardants (proprietary) waiting for tests under the FM 4996 or UL 2335 test protocols. A third company also has a new non-decaBDE flame retardant plastic pallet awaiting testing, but reportedly is substituting another brominated flame retardant for decaBDE.

Finding 5: *The primary polymers for plastic pallets are polypropylene, polyethylene and high density polyethylene.*

These polymers provide a unique blend of processing characteristics and end-use physical properties that enable the production of plastic pallets. These polymers are also commodities and therefore have very favorable economics for a high volume application such as pallets. We identified only one company manufacturing a plastic pallet with a different polymer (PVC), but two companies provided no information on what polymer they are using.

Finding 6: *Much of the information on flame retardant formulas and use is confidential.*

We were unable to obtain information on the amounts of flame retardants used by manufacturers, though the report does include expert estimates of the flame retardant percentages required to make a plastic pallet that could meet both flammability and performance standards.

Industry Use of Plastic and Wood Pallets (Task 10, Chapter 1)

Finding 7: *Direct purchasing and “open pool” leasing of pallets are two largely distinct markets with different demands for pallet performance attributes and flame retardants.*

The largest market for shipping pallets is for sales to companies for their own use, either within their facilities or in a ‘closed loop’ with other facilities in their own organization or group. The “open pool” leasing market involves shipping of rapid-turnover consumer goods (groceries, beverages, consumer electronics, cleaners, etc.), sent from major producers to different types of warehouses all over the country. Even the approximately 90 million “grocery” (40” x 48”) pallets in use in open pool leasing are only a small part of overall pallet use for consumer goods.

Finding 8: *In both open-pool and captive markets, wood pallets represent the overwhelming majority of pallets sold and used.*

Though estimates are very rough, approximately 90% of the entire universe of almost 3 billion pallets is wood. In the open-pool market, there are over 70 million wood pallets managed by two of the three large, open-pool companies (CHEP and PECO), and about 10 million plastic pallets managed by the other large, open-pool company, iGPS.

Plastic Pallets and Warehouse Fire Protection Rules (Tasks 3-5; Chapter 2)

Finding 9: *The National Fire Protection Association (NFPA) establishes standards for preventing and reducing the severity of warehouse fires that form the basis for laws, ordinances*

and regulations for sprinkler systems and best management practices throughout the U.S., including in Maine.

The NFPA 13 standard, which establishes fire protection requirements for warehouses, provides the basis for state and local warehouse fire prevention laws and is often adopted by reference. In Maine, state warehouse fire protection rules are governed by NFPA. In a few cases (e.g., Scarborough, Gorham, Westbrook), local Maine fire departments regulations have specific provisions that are more stringent than NFPA 13, but none of these relate to plastic pallets.

Finding 10: *Because the polymers (PP, HDPE) used in plastic pallets burn with twice the heat of wood, warehouse fire protection requirements for non-flame retardant plastic pallets are more stringent than those for wood pallets. While warehouses built and managed in accordance with NFPA's highest protection standards can accommodate non-flame retardant plastic pallets (one of the markets for captive direct sale pallets), some of the warehouses receiving open-pool pallets meet minimum, although fully legal, standards that provide too little protection against fire risks from such pallets.*

Because of the added potential intensity of plastics fires, NFPA 13 requires upgraded protection and stricter management for storage facilities using non-flame retardant plastic pallets. For many older or smaller operations, the necessary upgrades would be far too costly. As a result, some warehouses can only accept flame retardant plastic pallets; since open-pool plastic pallets can go to any warehouse, they must be flame retardant.

Finding 11: *The two large scale fire testing protocols, UL 2335 and FM 4996, used to determine whether a flame-retardant plastic pallet can be handled the same way as a wood pallet in a warehouse, are both described in the NFPA 13 Handbook, and by the Maine Fire Marshal Office, as acceptable, but not everyone agrees.*

Both UL 2335 and FM 4996 fire test protocols are used to determine if a plastic pallet is equivalent to wood for purposes of NFPA 13. The tests are different (e.g., both involve tests of idle pallets, but only UL tests pallets loaded with commodities, and only FM 'weathers' specimens to determine if they lose their flame retarding ability). While commentary in the NFPA handbook (which is not an official part of the standard) and most people we contacted accept both, we heard objections that, since FM 4996 doesn't test pallets with commodities, only UL 2335 is acceptable.

Reasons for Selecting DecaBDE or Non-halogenated Alternative Flame Retardants for Plastic Pallets (Tasks 6 & 7; Chapters 3 & 4)

Finding 12: *The three major families of potential flame retardants for plastic pallets are halogenated (predominantly brominated), metal hydrate (e.g., magnesium hydroxide) and phosphorus-based (e.g., ammonium polyphosphate).*

The traditional workhorses have been halogenated flame retardants, though growing regulatory efforts to eliminate the environmental and human health impacts of brominated flame retardants have resulted in increasing research into the other flame retardants.

Finding 13: *When flame retardants are added to plastic, they can have negative effects on key pallet characteristics such as strength, weight and durability, and can make a compound too costly or too unmalleable to process. Industry experts try to design flame retardant/plastic recipes that balance these competing demands. DecaBDE became the flame retardant of choice for many companies because relatively little was needed to be effective; it had fewer adverse impacts on pallet characteristics than other flame retardants; and it was inexpensive.*

When mixed with HDPE, less than 10% decaBDE is required to achieve the required flame retardant protection level for the UL 2335 and FM 4996 tests. Magnesium hydroxide, by contrast, may require as much as 25%, which can severely impact other needed characteristics of the pallet. Until recently, the only non-decaBDE flame retardant plastic pallet on the market was Rehrig Pacific Company's pallet with a magnesium hydroxide-based flame retardant. CHEP has just started to manufacture (December 2010) a proprietary, phosphorus-based flame retardant pallet that has passed UL 2335 and FM 4996. We do not have technical information on either.

Potentially Applicable Flame Retardants for Plastic Pallets (Task 8; Chapter 5)

Finding 14: *On the basis of information provided by flame retardant experts, manufacturers, compounders, and discussions with participants in EPA's Design for the Environment (DfE) workgroup on alternatives to decaBDE for various uses, the most promising non-halogenated flame retardants for toxicological review with the Green Screen, including both primary and supplemental flame retardants, were red phosphorus, ammonium polyphosphate, ethylenediamine phosphate, melamine polyphosphate, magnesium hydroxide, aluminum trihydroxide, zinc borate and magnesium stearate.*

While there is a longer list of potential alternative flame retardants under review by DfE, many are viable alternatives for fabrics or other applications that require very different performance characteristics from those required for plastic in pallets.

Environmental and Human Health Safety of Alternatives (Task 9; Chapter 6)

Finding 15: *The evaluation of the eight non-halogenated flame retardants selected for potential application in plastic pallets demonstrated that several potential alternatives for decaBDE do exist from a human health and environmental safety standpoint.*

Of the eight alternative non-halogenated flame retardants:

- One received a Green Screen score of 4 (“Safer Chemical”): ammonium polyphosphate.
- Six received Green Screen scores of 2 (“Use but Search for Safer Substitutes”): aluminum trihydroxide, ethylenediamine phosphate, magnesium hydroxide, magnesium stearate, melamine polyphosphate, zinc borate
- One received a score of 1 (“Avoid, Chemical of High Concern”): red phosphorus

Assessment of Functional Equivalence of Non-Halogenated Flame Retardant Plastic Pallets and Wood Pallets with DecaBDE Flame Retardant Plastic Pallet (Tasks 11 & 12; Chapters 7 & 8)

Finding 16: *Based on the first DEP criterion for functional equivalence, a strict comparison against all the GMA specifications, there is no functionally equivalent alternative pallet to the plastic pallet containing decaBDE.*

Four pallets meet the criteria established in Task 11 for comparison with the decaBDE flame retardant pallet – two wood pallets used in the open-pool leasing market and two plastic pallets with non-halogenated flame retardants. None of these meet all the GMA specifications. Three (the two wood pallets and the CHEP plastic pallet) exceed 50 pounds, and the fourth (the Rehrig Pacific plastic pallet) does not meet the 2800-pound rack capability requirement. The two CHEP pallets also fall short on top and bottom surface coverage specifications, though the iGPS decaBDE pallet also falls short on bottom surface coverage.

Finding 17: *Based on the second DEP criterion for functional equivalence, that the pallet currently is used by the grocery industry or other market sectors to ship the same types of good shipped on pallets containing decaBDE, there is a functionally equivalent alternative to the plastic pallet containing decaBDE.*

Both the PECO and CHEP wood pallets are currently used in the open-pool market to ship the same types of goods as the decaBDE containing pallets distributed by iGPS. In fact, the CHEP pallet, whether the all-wood pallet or the pallet with composite blocks, dominates that market. In addition, it seems plausible that the CHEP non-halogenated flame retardant pallet that went into production in December 2010 will soon be used in that market.

Structure of Assessment & How Future Assessments Might Be Structured

Maine DEP is participating in a multi-state effort to develop a stronger, more unified approach to the design and implementation of alternatives assessments. Assessments of safer alternatives to the use of toxic chemicals in products often focus primarily on the assessment of available chemical substitutes for the function served by the chemical to be replaced. This is both valuable and extremely important, and in many cases may be the only route to a solution. The use of the Green Screen for this report provided just such an assessment of alternative chemicals that could be used as flame retardants.

But Maine DEP also designed this study to assess the safer alternatives that might be developed through a focus on the structure and operations of the industry. This is not always incorporated as a systematic component of the alternatives assessment. In this study, this meant looking at fire protection systems and pallet management practices that might provide alternatives to the use of flame retardants as a methodology for meeting the requirements of NFPA 13. While, in the short term, the stock of older and less protected warehouses makes a solution based entirely on these factors insufficient, the design helped to broaden the perspective in the study to include ways in which environmental health and fire protection goals could converge in future planning.

Significant Gaps in Scientific or Technical Data on Alternatives

In order to evaluate the alternatives for decaBDE, a direct comparison of the performance characteristics of the pallet as well as the physical properties of the plastic compounds made with non-halogenated flame retardants was needed.

The major challenges to accomplishing this were:

- 1) *Gathering data on the physical properties of plastic compounds made with non-halogenated flame retardants and decaBDE.* Manufacturers of decaBDE were reluctant to supply data on plastic compounds made with decaBDE. Plastic compounders were reluctant to supply information on proprietary compounds containing flame retardants,

made for pallets. Manufacturers of non-halogenated flame retardants did supply some data that was generated on their products, but comparisons to decaBDE were only available from one manufacturer.

2) *Gathering data on plastic pallets made with non-halogenated flame retardants that are still in the development stages.* This was difficult because pallet manufacturers do not want to prematurely release information on a new product. The pallet performance characteristics are the pallet attributes shown in Table 7.1.

- Specific data on physical properties of modulus, impact resistance, melt flow index and specific gravity was generally not available from either manufacturers of plastic pallets or plastic compound manufacturers. The data is necessary to compare the effects of non-halogenated flame retardants and the decaBDE flame retardant on plastic compounds and, consequently, pallets.
- Manufacturers of plastic pallets did not provide specific information on the combinations and concentrations of the flame retardants used in their pallets. However, industry experts provided some general information on the use of decaBDE in plastic pallets.
- Reliable, accurate information on the total market, market segments, the percentage use of plastic pallets, both flame retardant and not, was hard to come by. The most comprehensive study had gaps on the issues related to flame retardance. Available surveys were useful, but targeted at specific audiences rather than the industry as a whole.
- A great deal of information that would be of interest – for example, information on what non-halogenated flame retardants pallet manufacturers are considering and what stage of development they are in – is proprietary.
- Accurate information on the effect of decaBDE on the physical properties of polyolefin plastic compounds from compounders, flame retardant and pallet manufacturers was generally not available. Most data gathered for this report was pieced together from a collection of reports, studies and product information sheets.
- Accurate information from pallet manufacturers on cost issues related to options for development of alternative non-halogenated flame retardants, or on market price constraints on options, is not publicly available. Once again, while such information would be valuable for understanding the incentives that could promote further development of non-halogenated flame retardant pallets, it is proprietary.